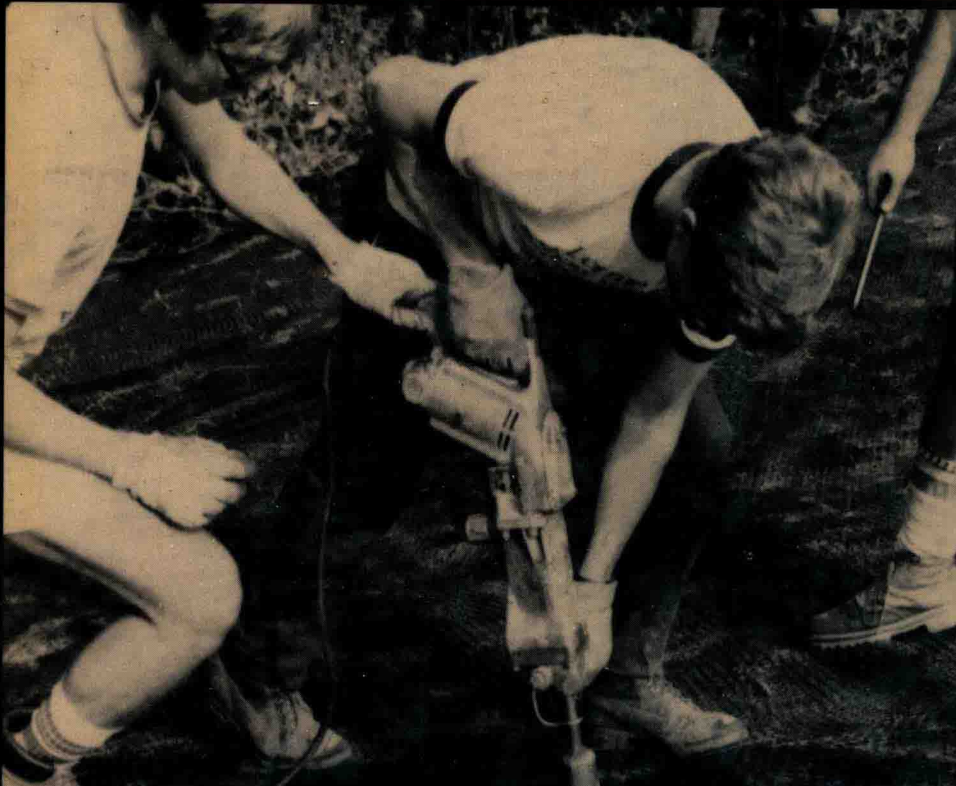
DESIGNING WITH GEOSYNTHETICS



Robert M. Koerner

Designing with Geosynthetics

Robert M. Koerner, Ph.D., P.E.

Bowman Professor of Civil Engineering
Drexel University

PRENTICE-HALL, Englewood Cliffs, NJ 07632

Library of Congress Cataloging-in-Publication Data

Koerner, Robert M.
Designing with geosynthetics.

Bibliography: p.
Includes index.
1. Geosynthetics. 1. Title.
TA455.G44K64 1986 624.1'51 85-25749
ISBN 0-13-201807-1

Editorial/production supervision
and interior design: *Sophie Papanikolaou*
Cover design: *Whitman Studio, Inc.*
Manufacturing buyer: *Rhett Conklin*

Major portions of the appendices are reprinted with permission of *Geotechnical Fabrics Report,* "1985 Product Reference Guide and Directory," Vol. 3, No. 6, Nov/Dec 1985. © 1985, Industrial Fabrics Association International (IFAI), 345 Cedar St., St. Paul, MN 55101.

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

ISBN 0-13-201807-1 025

Prentice-Hall International (UK) Limited, *London*
Prentice-Hall of Australia Pty. Limited, *Sydney*
Prentice-Hall Canada Inc., *Toronto*
Prentice-Hall Hispanoamericana, S.A., *Mexico*
Prentice-Hall of India Private Limited, *New Delhi*
Prentice-Hall of Japan, Inc., *Tokyo*
Prentice-Hall of Southeast Asia Pte. Ltd., *Singapore*
Editora Prentice-Hall do Brasil, Ltda. *Rio de Janeiro*
Whitehall Books Limited, *Wellington, New Zealand*

Dedication

To the manufacturers of geosynthetic products — the real pioneers (and gamblers) of this industry.

Preface

The development and utilization of geotextiles, geogrids, geomembranes, and geocomposites in subsurface construction works has been nothing short of awesome. These products, which in this book are collectively called *geosynthetics,* have risen from a relatively minor and specialty product status to a worldwide billion dollar industry in a ten-year period. To my knowledge, no other specific class of items in Civil Engineering and related construction activities has had such a dramatic increase in so short a time span. The current situation is both exciting (due to the newness and unknown challenges posed by the products) and dangerous (due to the obvious uncertainties involved). This rapid rise poses at least three interesting questions:

Why has it taken so long for these products to be developed and used?
What, or who, are the prime movers in their development and use?
What is the future of this technology and the related industry?

The first question is perhaps the most difficult to answer. Engineers and contractors have long tried to reinforce soft soils with dissimilar materials. Why polymeric materials took so long to emerge is not known. Perhaps the answer is due to the inherent conservatism of the civil engineering community or due to the poor initial performance of plastic materials after their introduction in the 1950s. A definitive answer is quite difficult to offer. The answer to the second question, on the other hand, is quite clear. The manufacturers of geosynthetic products have been the prime movers in the industry and in so doing have done a superb job. Consisting almost entirely of people other than civil engineers, these technical entrepreneurs have sensed the need, developed the products, aggressively marketed these products and have done so in an open and competitive manner. The third question appears to have two answers. The future for geosynthetic products seems very strong for continued growth merely by extending the present situation. Continued exposure to design and contracting professionals and education of students is certainly at the heart of this thrust. However, a different answer in predicting the future for geosynthetic products lies in the nature of the products yet to be developed. If new concepts involving threads, spirals, tubes, and other shapes come into being and are combined with themselves or with existing synthetic materials, an entirely new thrust will most likely occur. Completely new application areas might result as well as extending those that exist. The resulting impact could well be as dramatic as is the recent past. Either way, the future for geosynthetics is indeed a bright one.

As noted, education will surely play a role in the development and implementation of geosynthetic materials, and this book is directed at filling at least part of this need. As a *textbook* it is oriented toward upper-class undergraduate and graduate students. The optimal background to handle the material is for civil engineering students with at least an introductory course in geotechnical engineering and, better still, a course in foundation engineering. With suitable assistance by the instructor, polymer engineering students, textile engineering students, and chemical engineering students can also function well in using the text. In fact, these other students bring skills and ideas into this course and are indeed refreshing and welcome. As a *professional*-level book, the various designs are meant to be both instructive and state-of-the-art. The book will be valuable to the geosynthetic community at large. Many sections contain designs that are illustrated by worked-out numerical examples so that self-teaching is possible. The references at the end of each chapter should be helpful in this regard.

The book is primarly in English units; a decision that was not easily reached. To be sure, S.I. units would be desirable from an international standpoint. Yet, for a new subject like geosynthetics to be communicated and understood by its primary audience (which is in the United States) impediments such as non-familiar units become learning obstacles. If demand warrants, this edition will be followed immediately by a future edition based completely on S.I. units.

Yes students, there are many homework problems at the end of each chapter. The author is a firm advocate of homework, and after *every* class period. These are the real building stones by which you progress and retain . . . an unavoidable necessity. The problems are given in the order that the material is presented in the chapter. However, they vary enormously in their difficulty—from simple one line answers, to true "bears." Hopefully, they will all be interesting and relevant to your course of study.

In the conceptualization of the book, I profited greatly by a series of design courses taught jointly with Dr. J. Richard Bell of Oregon State University. My sincere appreciation is extended to him. Many discussions with Drs. Arthur E. Lord, Jr., Joseph P. Martin, and Frank Ko of Drexel University were extremely helpful. Numerous Drexel University graduate students have also been involved in various aspects of the book's development including their individual thesis projects—They are F. J. Arland, J. A. Bove, R. B. Crawford, W. W. Dougherty, A. J. Felser, J. L. Guglielmetti, B. -L. Hwu,

G. R. Koerner, C. A. Lawrence, E. C. Lindhult, V. A. Luciani, M. J. Monteleone, I. Oncu, J. C. Robins, J. E. Sankey, R. H. Swan, and J. E. Whitty. Particular thanks are extended to Ms. Marilyn Macklin, who typed and retyped the text numerous times.

Robert M. Koerner
Philadelphia, Pennsylvania

Contents

1

An Overview of Geosynthetics

1.0 INTRODUCTION

An exciting new concept in engineered materials has emerged for the civil engineering community—and the rapidity at which the related products are being developed and used is nothing short of amazing. No time in the author's experience have new materials within a specific area come on so strong. The reasons for this are numerous, among which are the following:

They are indeed needed.
They can be rapidly installed.
They generally replace raw material resources.
They generally replace difficult designs using conventional materials.
Their timing is very appropriate.
They are being aggressively marketed.

The professional groups most strongly influenced are geotechnical engineering and heavy construction, although all soil- and rock-related activities fall within the general scope of the various applications. This being the case, the prefix "geo" seems appropriate. The realization that the materials are almost exclusively from human-made products gives the second part to the name—"synthetic": thus the term *geosynthetics*. The materials used in their manufacture are primarily from the plastics industry, although rubber, fiberglass, and other materials are sometimes used.

The sections that follow in this opening chapter lay out the subcategories within the geosynthetics area and serve to set up the main body of the text, Chapters 2 to 5.

1.1 BASIC DESCRIPTION OF GEOSYNTHETICS

Lost in the pages of history are the initial attempts to reinforce soils with dissimilar materials possessing properties that would enhance the behavior of the soil itself. It seems reasonable to assume that it was attempted to stabilize swamps and marshy soils using tree trunks, small bushes, and the like. These soft soils would accept the fibrous material until a mass was formed that had adequate properties for the intended purpose. It also seems reasonable to accept that continued use of such a facility was possible due to the properly stabilized nature of the now-reinforced soil (probably by a trial-and-error procedure), or impossible due to a number of factors, among which were:

Insufficient reinforcement materials for the loads to be carried
Pumping of the soft soil up through the reinforcement material
Degradation of the fibrous material with time, leading back to the original unsuitable conditions

Such stabilization attempts were undoubtedly continued with the development of a more systematic approach in which timbers of nearly uniform size and length were lashed together to make a mattressed surface. Such split-log "corduroy" roads over peat bogs date back to 3000 B.C. [1]. This art progressed to the point where the undulating surface was filled in smooth and some of these systems were surfaced with a stabilized soil mixture or even paved with stone blocks. Here again, however, time deterioration of the timber and its lashing was an obvious problem.

The concept of reinforcing poor soils has continued until nearly the present day. The first use of fabrics made from natural fibers to reinforce roads was attempted by the South Carolina Highway Department in 1926 [2]. They used a heavy cotton fabric on a primed earth base, applied hot asphalt on the fabric, and covered this with a thin layer of sand. They published their work in 1935, describing eight separate field experiments. Until the fabric deteriorated, the results showed that the roads were in good condition and that the fabric reduced cracking, raveling, and localized road failures. This project was certainly the forerunner of the separation–reinforcement function of geosynthetic materials as we know it today.

Another major topic area for the purpose of this book is that of providing an intermediate barrier between two dissimilar materials for the purpose of water drainage and soil filtration. When requiring water flow across this barrier it must obviously be porous, yet not so much as to lose the retained soil—thus the necessity of using some sort of intermediate material. Again the historical development of attempts at filtration are important to set the stage for the work to follow. Run-of-bank gravel which was found to be naturally well graded had been used as filter material since ancient times. Purification by means of running polluted water through soil is an outmoded concept but still apparently used on occasion. The idea of systematizing the process seems to have been originated by K. Terzaghi and A. Casagrande in the 1930s and brought to use by Bertram [3] shortly thereafter. This idea of soil filters, even multiple-graded soil filters, is a target area for the materials described in this book—*not* for reasons of degradation, however, but for cost efficiency.

Thus the two-pronged thrust of this opening section is to establish the major targets for which synthetic fabrics are aimed. This is to do the intended job better (e.g., no deterioration of material) and to do it less expensively (i.e., either in initial cost or in longer life and less maintenance).

I call the general area "geosynthetics," recognizing that the materials are used in soil and are synthetic (usually made from hydrocarbons). The specific families of geosynthetics on which we will focus are the following:

Geotextiles
Geogrids
Geomembranes
Geocomposites

which are shown for comparative purposes in Figure 1.1.

1.1.1 Geotextiles

Geotextiles form the largest group of geosynthetics that will be discussed in this book. Their rise in growth during the past 10 years has been nothing short of awesome. They are indeed textiles in a traditional sense, but consist of synthetic fibers rather than natural ones like cotton, wool, and silk. Thus biodegradation is not a problem. The fibers are made into a flexible, porous fabric by standard weaving machinery or are matted together in a random, or nonwoven, manner. Some are also knit. The major point is that they are porous to water flow across their manufactured plane and also within their plane, but to a widely varying degree. There are at least 80 specific application areas for geotextiles that have been developed; however, the fabric always performs at least one of five discrete functions:

1. Separation
2. Reinforcement
3. Filtration
4. Drainage
5. Moisture barrier (when impregnated)

Geotextiles, with an orientation toward these functions, form the basis of Chapter 2.

1.1.2 Geogrids

Geogrids represent a small, but rapidly growing, segment of the geosynthetics area. Rather than being a woven, nonwoven or knit textile (or even a textilelike) fabric, geogrids are plastics formed into a very open netlike configuration. Often they are stretched in one or two directions for improved physical properties. By themselves, there are at least 25 application areas, and they function in two ways:

1. Separation (occasionally)
2. Reinforcement (usually)

Geogrids form the basis of Chapter 3.