Chapter 1

Introduction

1.1 Background

The concept of the reinforcement of cohesionless soil with cellular confinement was first introduced in the 1970's. This development was stimulated by the U.S. Army's need to stabilise beach sand for roadways. Since these early days the most common use of the geocell system has been the reinforcement of soil in the construction of roads. Other applications have been the improvement of the bearing capacity of soil under foundations and slopes, channel linings and erosion protection. Figure 1.1 shows photographs of the geocell system in some of these applications. In the last couple of decades the geocell systems have also been used in the construction of flexible gravity structures and the facia of geosynthetic reinforced soil retaining wall structures and steepened slopes (Figure 1.2).

Although these widely different application of cellular confinement systems demand a better understanding of the fundamental behaviour of the functioning of the cellular reinforced soil system, surprisingly little research on the fundamental behaviour of the structures and the interaction of the components have been done.

Recently the use of cellular reinforced soil systems for underground mining support packs (Figure 1.3) has been proposed. The need to understand and predict the strength and stiffness behaviour of such systems further highlights the shortcomings in the current state-of-the-art as current theories do not take the non-uniform deformation mode, nor the volume change of the soil into account and are aimed at estimating the peak strength of the geocell system only.

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The need therefore exists for research into the functioning of cellular reinforced soil systems to improve the understanding of the interaction of the components of the system and each component's contribution to the strength and stiffness behaviour of the composite structure. Such a research project was initiated at the University of Pretoria and this thesis constitutes the first step in achieving an understanding in the functioning of geocell reinforced soil systems. The research reported on in this thesis, is focused specifically on the geocell support pack configuration, as this was the main interest of the project sponsors. The research output is, however, not limited to this configuration and may find wider application.

1.2 Objectives and scope of study

The objective of the study is to investigate the stiffness and strength behaviour of geocell support packs under uniaxial loading and advance the state-of-the-art in understanding the functioning of geocell support packs under uniaxial loading.

This study aims at providing an understanding of the functioning of the geocell support pack by:

- Studying the constitutive behaviour of the fill and membrane material and providing practical and simple mathematical models to quantify the most important components of the constitutive behaviour of both the fill and membrane material, which can be incorporated into analytical and numerical procedures to model the composite behaviour.
- Provide a theory for combining these mathematical models into a calculation procedure for estimating the stress-strain response of cohesionless soil reinforced with a single geocell.
- Provide an understanding of the behaviour of multi-cell packs by studying the behaviour of the multi-cell structure with respect to that of the single cell structure.

The subject at hand is influenced by numerous parameters, many of which have an unknown influence. In order to allow a manageable project it was, however, necessary to impose certain limitations.

Only one soil type is used in this study, namely, classified tailings. Classified tailings are tailings that have been cycloned at the mine's backfill plant to

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reduce the < 40 μm fines content. Classified tailings are widely being used in mines as a backfill in stopes to provide regional support and are a logical choice as a fill material for geocell support packs.

The load deformation behaviour of geocell support packs is influenced by the aspect ratio of the pack. For a thin mattress-like pack with a high width to height ratio, the confining effect of the top and bottom ends will have a much greater influence on its behaviour than for a slender pack. Due to the confining effects of the top and bottom ends a mattress-like pack will show load deformation behaviour resembling that of the one-dimensional compression behaviour of the fill material. A very slender pack, on the other hand, will be prone to buckling deformation. Between these two extremes the packs function in a uniaxial compression mode with a freedom for horizontal dilation (Figure 1.4). This study was limited to this deformation mode and the aspect ratio of the packs was kept constant at a width to height ratio of 0.5.

The behaviour of the geocell support pack, when installed in the mining environment will be influenced by several other factors such as temperature, damage during installation and during its life, and the physical and chemical durability of the geocell membrane. Although these factors are important for quantifying the underground performance of these packs, they were excluded from the current study.

1.3 Methodology

Geocell reinforced soil structures are composite structures consisting of the soil fill and the plastic membranes and its constitutive behaviour is ultimately determined by the constitutive behaviour of the constituting components and their interaction. An understanding of the constitutive behaviour of both the soil and the geocell membranes, therefore, is a prerequisite for the understanding of the composite behaviour.

Basic indicator tests, particle size distribution, specific gravity, Atterberg limits and minimum and maximum density tests were performed on the classified tailings fill material. This series of tests enabled the classification and comparison with other granular material. Light and Scanning Electron Microscopy were performed on different particle size ranges to obtain some appreciation for the particle scale properties of the material to give further insight into the material behaviour. Isotropic and triaxial compression and

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oedometer tests were also performed on the classified tailings material at different initial densities, enabling a study and quantification of the constitutive behaviour of the classified tailings fill material.

Specimens of the HDPE (High Density Polyethylene) membrane material were tested uniaxialy at different constant strain rates. This enabled the investigation into the strain rate dependent stress strain properties of the membrane material and the development of two mathematical models for the strain-rate-dependent stress-strain behaviour of the membrane material.

The insight and predictive capabilities obtained from the study of the classified tailings fill material and the HDPE membrane material was then combined into a theory for the prediction of the stress-strain behaviour of soil reinforced with a single geocell. The results of the single cell laboratory compression tests enabled the comparison and refinement of the developed theory.

Instrumented compression tests on a 4 cell (2x2) composite structure as well as a 9 cell (3x3) and a 49 cell (7x7) composite structure were performed to enable the investigation into the behaviour of multi-cell composite structures.

1.4 Organisation of thesis

The thesis consists of the following chapters:

Chapter 1 serves as an introduction to the report.

Chapter 2 presents a literature review on the reinforcement of soil with cellular confinement. From the literature review the need for the current research is established and the specific issues addressed in this thesis, stipulated.

Chapter 3 describes the laboratory testing programme and presents the results from the testing programme. The laboratory testing programme consisted of three parts which dictates the structure of this chapter i.e.: the laboratory testing of the soil, the tests on the geocell membrane material, and laboratory tests on the composite structures.

The data presented in *Chapter 3* are critically evaluated, interpreted and discussed in *Chapter 4*. This discussion leads to an increased understanding of the constitutive behaviour of the components of the composite geocell structure and their interaction and the development of procedures for the mathematical modelling of the constitutive behaviour of the soil reinforced with a single

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geocell. This theoretical work then aids the understanding of the strength and stiffness behaviour of multi-cell composite structures.

Conclusions flowing from the work presented in the earlier chapters are presented in *Chapter 5*.

For the sake of readability of *Chapter 4*, some parts of the discussion is documented in more detail in the *Appendices* and summarised in *Chapter 4*.

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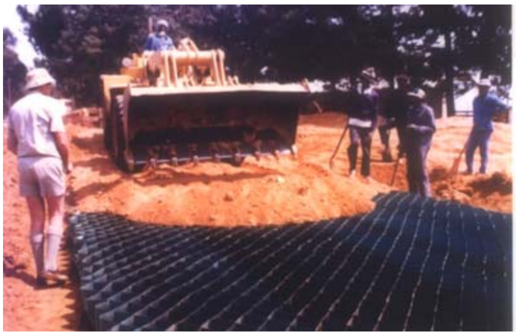
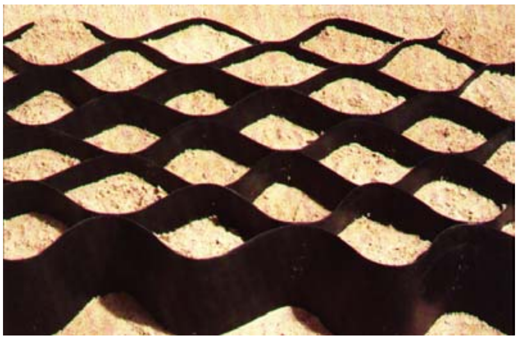
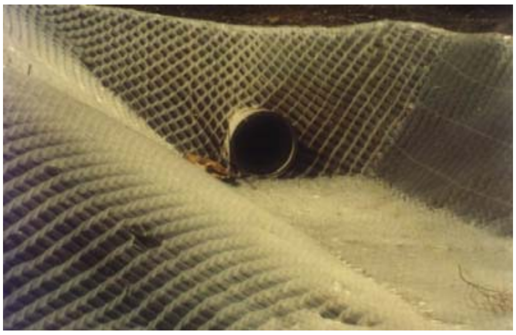
a) Unfilled geocell mattress.



b) Mattress being filled with soil.



c) Geocell mattress half filled with sand.



d) Geocell for storm water channel lining.

e) Geocell channel lining being filled with concrete.

f) Geocell retaining structure.

Figure 1.1 *Illustration of the geocell cellular confinement system. (Photographs* (a)*,* (b)*,* (d), (e) *and* (f) *with courtesy from M & S Technical Consultants & Services, photograph* (c) *with courtesy of Presto Geosystems.)*

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a) b) c) d)

Figure 1.2 *Illustration of the geocell retaining structures. (Photographs* (a), (b) *and* (c) *with courtesy from Presto Geosystems, photograph* (d) *with courtesy from M & S Technical Consultants & Services.)*

a) b)

Figure 1.3 *Illustration of the geocell retaining structures. (Photograph* (b) *with courtesy from M & S Technical Consultants & Services.)*

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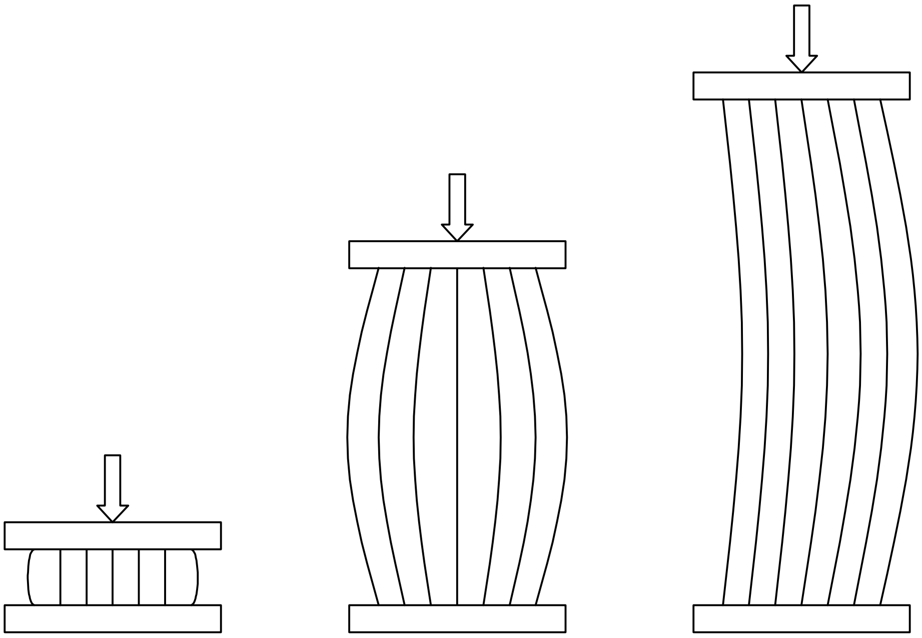

a) One dimensional compression. b) Uniaxial compression. c) Buckling.

Figure 1.4 Illustration of the probable deformation modes for different pack aspect ratios.