CHAPTER 1
INTRODUCTION

1.1 Introduction

An increase in infrastructure development leads to a decrease in best-suited land for civil engineering constructions and hence it has forced the construction of structures on weak soils. Civil engineering structures founded on weak soils often pose design, construction, and maintenance challenges. Construction of any engineering structures on such soils may lead to load-bearing capacity or excessive settlement failure, and hence generally ground improvement methods are used to mitigate this type of problem. Among various ground improvement methods, the soil reinforcement method is widely adopted and appreciated for its ease of construction and application, and economical, and environmental feasibility.

The techniques of reinforcing soil mass have been practiced for centuries in a variety of ways, including with straw, reed, bamboo, timber, etc. [32, 59]. However, it wasn't until Henry Vidal [134] that systematic worldwide research in this area was conducted and he is considered the pioneer of the 'Reinforced Earth', technique, which is now the general term used to describe all forms of soil reinforcement. Over time, soil reinforcement has been updated and modified using new materials and designs, starting with metallic strip reinforcements, then polymeric sheet-type reinforcement, and now, the widely used geosynthetics in various forms.

1.2 Geocell reinforced soil

The idea of enhancing behaviour of soil by confining it with cell-like structures was effectively adopted in the year 1970 by the US Army Corps Engineers [106, 135, 137]. Flexible strips of plastic were welded to prepare interconnected cells which were laid on and filled with poorly graded sandy soil to enhance their bearing capacity. Limited use of resin-coated paper, metal sheets like aluminum, etc. as geocell material was also made previously but was found unsustainable as they were difficult to be handled in the field and costly. With the commercial availability of geogrid sheets geocells made of these sheets using bodkin bars at joints [16], also known as perforated geocells, have also found application. One of the most common materials used for the manufacture of geocells nowadays is high-density polyethylene, strips of which are welded in a honeycomb structure. Geocells come in various shapes and sizes. A typical example of a geocell available in the market with an on-site application is shown in Figure 1.1.

Fig. 1.1 Typical geometry and readymade geocell structure with on-site application

The reinforcement principle behind geocells is based on the confinement of soil in its pockets, also known as the lateral resistance effect (Fig. 1.2a). Unlike planar reinforcement, geocell confinement reduces the lateral spreading of the soil fill within the geocell and thus, acts like a rigid layer intersecting the planes of potential failure and driving these planes to higher depth under the footing. This mechanism leads to the enhancement of load-carrying capacity due to the resultant increased surcharge load. Vertical stress dispersion effect due to the introduction of stiffer materials (Fig. 1.2b), and membrane effect because of an anchorage on both sides of the loaded soils also play an important role in increasing the load-carrying capacity (1.2c). However, these three factors are influenced by various parameters such as the geocell pocket size, height of geocell layer and width of the geocell layer, depth of placement of geocell layer, stiffness and strength of reinforcement materials, relative density or strength of subgrade soils, types of infill materials and relative density of infill materials on the performance of geocell-reinforced soils.

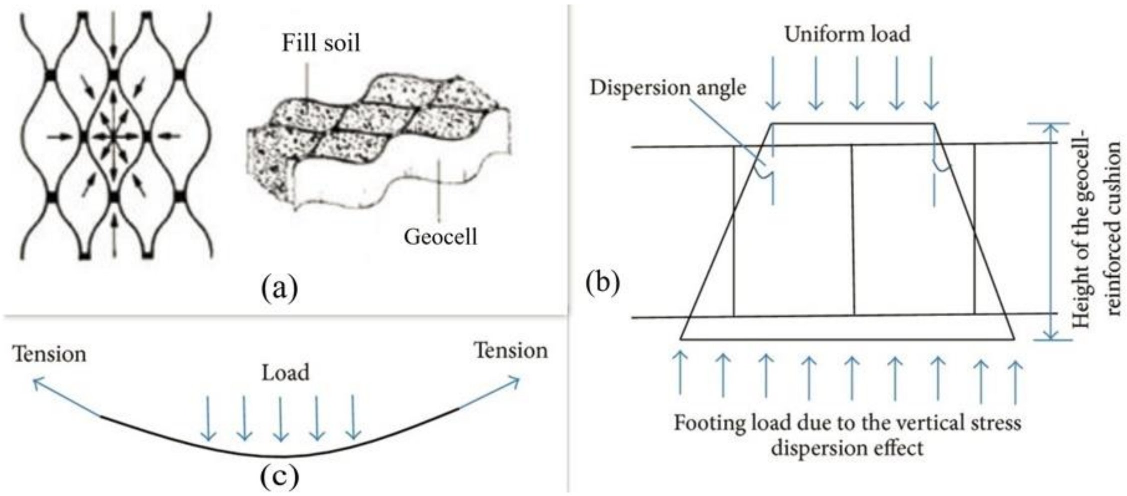

Fig. 1.2 Reinforcement mechanism of geocells by (a) Soil confinement; (b) vertical stress dispersion effect; (c) membrane effect (Zhang et al. [141])

1.3 Need for research

Review of the literature regarding geocell-reinforced foundation shows that most of the previous studies are focused on the performance of foundations reinforced with geocell under a single shape of footing i.e., either circular, square, or strip footing. The earlier studies are mostly related to the performance benefits of a single type of footing on geocell-reinforced soils. Nevertheless, no studies have been performed to understand the effect of the shape of footing on geocell-reinforced soils. Since, in practice, different shapes of footing may be required to support a structure, therefore, it is important to understand the effect of the shape of footing on geocell-reinforced soils.

In the geocell-reinforced foundation's system, various geocell geometry such as geocell pocket size (*d*), the height of geocell layer (*h*) and width of geocell layer (*b*), depth of placement of geocell layer (*u*), stiffness of reinforcement layer (*k*), and relative density of infill sand ($D_{r,\ infill}$) are the primary concern of studies. Although several studies were conducted to evaluate the performance of geocell-reinforced sand beds in respect of these parameters of the geocell reinforcement, however, those studies dealt with only static loads. Further, most of those studies were related to geocell made from geogrids or factory-made geocells of polymeric materials. Moreover, in earlier studies, the influence of relative density of subgrade sand (D_r) was not considered on the performance behaviour of reinforced sand.

Concerning the response of sand with geocell reinforcement under repeated loading, in most of the previous studies, the focus was on low to high-frequency repeated loads. However, there are some structures like petroleum tanks, water tanks, parking yards, etc. where the frequency of loading and unloading is very low. Further research, therefore, is required to understand the behaviour of geocell-reinforced sand beds under repeated loads at very low frequencies. Moreover, there is a need for research to understand the effects of various parameters such as *d*, *h*, *b*, *u*, and D_r on the performance of geocell-reinforced sand under repeated loads.

Further, an extensive review of the literature indicated that only a few researchers have attempted to propose an empirical method for estimating the load-carrying capacity of geocell-reinforced sandy soil. Hence, there is a need for research to develop a simplified formula (considering the influencing parameters) for the estimation of the load-carrying capacity of geocell-reinforced sand, so that practicing engineers can easily predict the bearing capacities for preliminary design work.

1.4 Objectives

To address the aforementioned research gap, this study deals with a series of small-scale model tests conducted to investigate the effect of various parameters such as footing shape, the relative density of sand subgrade, geocell geometric dimensions, and relative density of infill sand (in the geocells) on the performance of geocell-reinforced sand under static and repeated loads. The study aims for a better understanding of the benefits of the use of geocells beneath the footing and determines the parameters controlling best usage under static and repeated loading.

1.5 Thesis Organization

The thesis is organized into seven chapters followed by a list of references, appendices, and a list of publications. The break-up and sequence of the chapters are as follows:

Chapter 1 deals with an overview of reinforced soil, statements of the problem, broad objectives of the study, and the structure of the dissertation.

Chapter 2 deals with a comprehensive review of previous studies on the domain of reinforced soil structure, and detailed objectives and scope of the present study.

Chapter 3 covers the materials used in the study, including their characterization and the methodology employed. It provides an overview of the test program, including the test setup, the preparation of foundation beds, and the experimental procedure.

Chapter 4 presents the results obtained from the static load tests performed on unreinforced and geocell-reinforced sand beds to investigate the effect of various parameters such as the effect of footing shape, relative density of sand subgrade, geocell geometric dimensions, and relative density of infill sand (in the geocells) on the performance improvement of geocell-reinforced sand beds. Three types of footing such as square, rectangular, and strip footings are used to investigate the effect of the shape of footing on unreinforced and geocell-reinforced sand foundations. Thereafter, a series of laboratory model load tests are carried out to investigate the influence of various parameters such as relative density of sand subgrade (D_r), geocell placement depth from the base of the footing (u), the equivalent diameter of geocell pocket (d), the height of geocell reinforcement (h), the width of geocell reinforcement (b) and relative density of infill sand in the geocells ($D_{r,\ infill}$) on the bearing capacity of geocell reinforced sand foundations under the square footing.

Chapter 5 presents the results obtained from the repeated load tests performed on unreinforced and geocell-reinforced sand beds of 70% relative density. The influence of various parameters such as initial static load levels, number of load cycles, depth of placement of geocell layer from the base of the footing, the equivalent diameter of geocell pocket, the height of the geocell layer, the width of geocell reinforcement and relative density of subgrade sand on the overall performance of the reinforced structure under repeated loads are also investigated and presented in this chapter.

Chapter 6 deals with the regression model to predict the load-carrying capacity of the reinforced foundation beds and comparison of the model with existing analytical methodologies.

Chapter 7 summarizes the findings of the study and draws conclusions based on the research. It also includes a brief discussion of potential future areas of research in the field.

References.
Appendix
List of publications.