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Review article

Improvement of Bearing Capacity of Shallow Foundation on Geotextile (Geosynthetics) Reinforced Soil

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Abstract
An important first step in understanding the issue of structural settlement is the investigation of bearing capacity under footings subjected to static loads. The strength of the foundation soil is known to affect the bearing capacity of shallow foundations. When shallow foundations are erected upon weak soils, they face several issues. Therefore, Weak soils must be improved using soil improvement techniques, such as soil reinforcing systems, which improve the soil's bearing capacity and decrease the settlement of structures. Many soil reinforcement methods have been developed. Some of the most commonly used techniques are: grouting, freezing, dewatering, compacting, soil mixing, geosynthetics, etc. Synthetic materials consisting of natural or polymeric materials are known as geosynthetics. such as geogrid, geotextile, geonet, and geocell are conventional reinforcement materials that can be used in three-dimensional structures, strips, or sheets in improved soil techniques. They may help with more environmentally friendly building projects and are simple to prepare and carry. The results of this review paper may be useful in knowing how to increase the bearing capacity of soil for shallow. The concept and principle of reinforcement of soil using foundations, and what are the ways to improve the ground with geosynthetics
Keywords. Bearing Capacity, Reinforced Soil, Geosynthetics, Geotextile.

Introduction

Studying bearing capacity under footings subjected to static stresses is an essential first step in understanding the problem of structural settlement. The bearing capacity of shallow foundations is known to be affected by the strength of the soil under the foundation. There are several issues when weak soils are used for shallow foundation construction. Thus, it is essential to use soil restoration procedures to strengthen the poor soils. These soil reinforcing technologies are used to lessen the settling of structures and boost the soil's bearing capacity. Numerous techniques for reinforcing soil have been developed. Among the most popular methods are soil mixing, grouting, freezing, dewatering, compacting, geosynthetic, and so forth. Natural synthetic materials composed of natural or polymeric materials are known as geosynthetics. strips, a sheet, or a three-dimensional structure as illustrated in Figure 1.

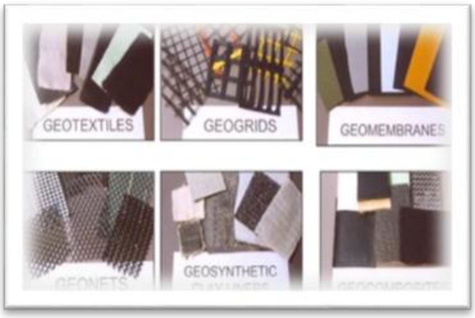

Figure 1. Type of geosynthetics

In 1969, Vidal developed the idea and principle of employing fibers to reinforce soil, discovering that the ad dition of reinforcing components to a soil mass increased the medium's shear resistance. Since the develop ment of numerous polymeric materials, primarily made from industrial fibers and possessing a variety of p roperties and applications, including industrial fabric and industrial net, soil reinforcing systems have adv anced efficiently.

These materials have been used in many different fields, but the most significant ones are the constructio n of roads on weak lands, railway bridges, and the bottom of marine facilities like protection of beaches, si dewalks, slopes, bridge abutments, retaining wall, and, lastly, the use of these materials to strengthen the soil below the foundations, as shown in figure 2 [1,2].

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Figure 2. Reinforcement of support structures

Numerous studies have been conducted to determine the advantages of utilizing reinforcement in soil, with a focus on examining the behaviour of reinforced soil foundations and how the features of the reinforced soil affect their bearing capacities, optimum placement position of geotextile from the base of the footing, and a number of reinforcement layers. Primarily, studies on the effect of soil reinforcement for the enhancement of the bearing capacity of footings were conducted by Binquet and Lee (1975) and subsequently pursued by many others. According to the findings of Akinmusuru and Akinbolade in 1981, alongside those of Guido et al. in 1985, it was found that when there are more than three reinforcing layers, the improvement in bearing capacity for a single reinforced footing is not very noticeable. [3][4][5]. Yet, Das and Omar (1994), along with Boushehrian and Hataf (2003), revealed something intriguing: when it came to a single reinforced footing, they found optimization at an, specifically when Nequaled 4 [6,7]. In a sand slope system, Altalhe and Taha (2012) assessed how one, two, and three reinforcing layers affected the strip footing's bearing capacity ratio (BCR). Reinforcement has a greater impact on sand's loading capacity in lower relative density soils than in higher relative density soils. Two reinforcements are the ideal quantity. Additionally, the most effective spacing between the two reinforcing layers is 0.3 B. The location of the footing about the slope face controls the increase in bearing capacity, in addition to the geotextile pattern [17].

A research of experimental model testing on the behavior of a strip footing supported by a row of soil nails and a single geotextile layer in a sandy slope was reported by Altalhe et al. (2013). According to the results, strip footing's bearing capacity is greatly increased when an earth slope is stabilized by one layer of geotextile or a row of soil nails as soil nail spacing gets smaller, this increase in bearing capacity gets bigger. When stabilizing an earth slope with a single geotextile layer as opposed to a row of soil nails, the overall benefit is much greater [18].

In order to enhance the bearing capacity of a local sandy soil and ascertain the impact of the depth of the synthetic fiber (jute) layer on the soil's stability characteristics and bearing capacity, Altalhe et al. (2020) examined how jute fibers behaved in reinforced sand. The bearing capacity of the soil can be enhanced by placing a layer of jute at a distance directly below the foundation, after which the effectiveness of the improvement decreases, and placing the jute becomes useless [19]. Altalhe et al. (2023) investigated the impact of jute geotextile application on the sandy soil's subsurface layer; the findings of laboratory load testing on model circular footings supported on reinforced sand beds are presented in this work. According to the experimental findings, the greatest increase in footings' ultimate loading capacity on supported soil (by jute geotextile) is viewed as expanded by a variable of 2.02 when compared with soil without jute geotextile. Also, verification of the experimental results of bearing capacity was compared with the theoretical bearing capacity. The Terzaghi equation and the experimental findings correspond well [20]. Nowadays, geosynthetics have been used as a routine reinforcement in earth structures such as retaining walls, bridges, and foundations. in all, geosynthetics, perform five major functions: separation, reinforcement, filtration, drainage and moisture barrier and geosynthetics can increase the bearing capacity of shallow foundations by improving the shear strength and modulus of the soil, increasing the friction and interlock between the soil and the foundation, and reducing the lateral displacement and bulging of the soil [8]. Nevertheless, the way they behave in soils and the properties of soils make it easier to understand the uses and functions of geotextiles. Thus, the detailed review in this research reveals that there is a dire need to design and engineer an innovative jute geotextile to suit the requirements of different geotechnical applications.

Geosynthetics and properties

Produced products primarily polymers, utilised in geotechnical applications are known as geotextiles The types of geotextiles can be classified into several different groups: geomembranes, geonets, geotextiles, geocells, geofoam, and geocomposite. Except for 3D honeycomb geocell and cubic geofoam, all other geotextiles are 2D or planar. Geojute, a fascinating material, comes from the lush jute plants that primarily

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thrive in India and Bangladesh. Lately, there's been a growing interest in harnessing the potential of jute geotextile (JGT) for a variety of civil engineering projects. This shift reflects an exciting trend toward eco-friendly solutions in construction and infrastructure development [4]. The results of this research work discuss the characteristics of geotextiles, which are briefly explained as follows:

Geotextiles Type

Geotextile can be non-woven, woven, or knitted as shown in Figure 3. Fibers are randomly arranged and joined by heat fusion, needle punching, or glue to create non-woven geotextiles. In the weaving process, the fibers are essentially placed in various configurations at right angles to one another to create woven geotextiles. Fibers are interlocked to create knitted geotextiles. Polypropylene (PP) polymers make up the majority of geotextiles. Other polymers include polyamide (nylon), polyester [such as polyethylene terephthalate (PET)], and polyethylene (PE) [9].

Figure 3. Geotextile products

Jute Geotextile (JGT)

In light of its texture that is similar to gold, Jute, known as a golden fibre it is a specific kind of lignocellulosic fiber used in textiles. Alpha cellulose makes about 62% of its chemical composition, followed by hemicelluloses (24%), lignin (12%), and miscellaneous substances (2%). It has an advantage over other geotextiles due to its low elongation at break (1.4%), toughness (40gm/tex), and moisture content (13%) at 65% relative humidity (Sridhar 2015:60). To improve the engineering properties of soil, JGT—a permeable fabric that can be woven or non-woven—is used. Refer to Figure 4.

Figure 4. Jute geotextile

Types of JGT available along with their Specifications

JGT customized goods. Depending on the needs of the final consumer, site-specific products can be produced. It is simple to create fabric that is wider (up to 5 m) and stronger (40 kN/m) with finer porometry (100 micron). Nonetheless, Table 1 below provides references to the specs of certain common JGTs [10].

Table 1. Specifications of widely used Jute Geotextile

Properties Type	*Weight*	*Thickness*	*Strength*	*Elongation*
Woven	760	2	20X20	10X10
Nonwoven	500	4	4X5	20X20
Open Mesh	500	4	10X7.5	-

Property Advantages

The characteristics of geotextile include significant strength and modulus, adequate dimensional stability, acceptable felt weight and tangible consistence, good draping quality, stiff body that prevents discriminational agreement on soil, high permittivity and transmittivity, irregular face morphology that prevents side and rotational slides, high water immersion that performs well in filtration, drainage, and soil connection (caking) functions, addition of minerals to the soil after a decrease eco-compatibility, foliage support, easy vacuity, low cost, and agro-renew capability.

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Particular Uses Applications

Jute Geo-Textiles (JGT) include subsurface drainage, soft soil consolidation, stabilizing embankments, bolstering subgrade soils in highways, protecting river and waterway banks, and controlling surface soil erosion on slopes and plains. As a result, JGT can tolerate pressures throughout the building process, prevent soil layers from mixing, operate as a separator, filter, and regulate slides, subsidence, and lateral dispersion. JGT carries out five fundamental tasks, including vegetation or biotechnical support, separation, filtration and drainage, initial reinforcement, and control of surface soil detachment.

Function

Geosynthetics play a multitude of roles that are essential to various engineering applications. Their primary functions—separation, filtration, drainage, reinforcement, barrier creation, and corrosion protection—are vital in ensuring the efficacy and longevity of construction projects. If you take a look at Table 2, you'll see how different types of geosynthetics correlate with these functions. standing out in a world where materials often take on heavy burdens. When two distinct geomaterials find themselves in close quarters, there's the risk of them blending under pressure, particularly when faced with cyclic stresses. That's where geosynthetics—like geotextiles and geomembranes—come into play! By inserting them between these materials, we maintain their integrity and prevent undesirable amalgamation, a function known as separation. This capability becomes particularly crucial when dealing with extremely fine soils, where the undrained shear strength dips below 15 kPa, typically at depths of about 5 to 10 meters. Geosynthetics do wonders here! They help enhance foundations, bolster bearing capacity, and stabilise structures while also effectively mitigating settlement issues, expediting the consolidation process. Dive into Table 2 to explore the world of geosynthetic functions.

Table 2. Function of geosynthetic

Type	Separation	Filtration	Drainage	Reinforcement	Erosion Protection	Barrier
Geotextile	√	√	√	√	√	√
Geogrid				√		
Geonet			√			
Geomembrane	√				√	√
GCL	√				√	√
Geocell				√	√	
Geocomposite	√	√	√	√	√	√

Jute Geotextile Standards, Properties, and Test Methods

For geotechnical applications, technical textiles must be properly tested to guarantee their efficient operation. The standards developed for this purpose pertain to geotextile, where the kind, extent, and character of the imposed load, as well as the texture and nature of the soil, essentially determine which JGT is best for a certain application in geotechnical engineering fields. Typically, geotextile testing procedures follow the guidelines set forth by ASTM International, formerly known as the American Society for Testing and Materials (ASTM), a globally recognized standards organization that creates and disseminates widely accepted technical standards for a variety of materials, goods, systems, and services. The ASTM testing technique and guidelines are used when there are no international standards for JGT [11].

Testing methods

The performance of individual JGT types for particular applications is the basis for the preparation of standards. A brief description of the methods used for parameter assessment in accordance with ASTM standards is provided below. Below are the test procedures that are typically used.

Breaking load and elongation of geotextile

This test measures the geotextile fabric's elongation (grab elongation) and breaking load (grab strength). This standard is mostly utilized in labs for acceptance testing and quality control when comparing geotextiles with similar or identical structures, whereby the specimen is subjected to a longitudinally applied load that keeps growing until it ruptures. Machine dials or scales, autographic recording charts, or interfaced computers are used to determine the test specimen's elongation and breaking load values [12].

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The mass per unit area of a geotextile
The purpose of this test procedure is to evaluate which the mass per unit area requirements of the geotextile material is met, Specimen conformity can be ascertained using this test method for quality control, ASTM D5261 – 10 to determine the mean mass per unit area of a laboratory sample, first weigh test specimens that have known dimensions. These specimens are carefully cut from different spots across the entire width of the sample we're examining. After gathering all the measurements, we crunch the numbers to calculate the values, and finally, we average them out to arrive at a comprehensive understanding of the sample's mass distribution. [13]

Water permeability of geotextiles by permittivity
Permittivity is an expressed of the quantity of water that can pass through a geotextile in an isolating condition due to different geotextiles have different thicknesses, assessing them in light of We are frequently misled by the Darcy coefficient of permeability. This idea, called permittivity, is essential when attempting to determine how much water will pass through a geotextile across a given area at a given pressure. It's a sophisticated metric that encapsulates the spirit of water movement through those textiles [14].

Nominal Thickness of Geosynthetics
Thickness stands out as a pivotal physical trait in assessing the quality of various geosynthetics. Indeed, several parameters, such as permeability coefficients, tensile stress (the index), and similar thickness, all hinge on these thickness values. When it comes to gauging the nominal thicknesses of geosynthetics, we look at how much a movable plane shifts vertically from a parallel surface when pressure is applied (specifically, 2 kPa for geotextiles and 20 kPa for geomembranes over 5 seconds). This testing method can certainly serve as a useful benchmark for accepting commercial shipments of geotextiles and geomembranes. However, a word of caution is warranted here; the data regarding inter-laboratory precision is still somewhat sketchy, so it's wise to proceed with care [15].

Tension and Elongation of Elastic Fabrics
This test method measures the tension and elongation of wide or narrow elastic textiles created from natural or synthetic materials, either by themselves or in conjunction with other textile yarns, when tested using a tensile testing machine of the constant-rate-of-extension (CRE) type. In a tensile testing apparatus, a conditioned loop specimen is installed. After reaching a set loop tension, the specimen is expanded at a predetermined pace and then brought back to zero tension at a predetermined rate. Three cycles are obtained by repeating the cycle twice more. Plotting of extension-recovery curves may be done by an automatic recorder for the entire test or just the third cycle, the test for measuring loop tension at specified elongation(s) is used to determine the tension of an elastic fabric when subjected to a specified elongation which is less than the elongation required to rupture the fabric [16].

Conclusion
It is found that applying jute geotextile to the soil can increase its bearing capacity. Among its many benefits, the JGT method of soil reinforcement has come out as one of the most economical and ecologically responsible ground improvement strategies used in modern construction. Applications for JGT-reinforced soils are numerous in the fields of civil engineering, Geotechnical applications, transportation applications, hydraulic applications, and geoenvironmental applications form the core categories that drive our understanding and usage of the earth and its resources. When it comes to the overall stability of a shallow foundation, especially one resting on weaker foundation soil, there's a fascinating strategy that can work wonders. Imagine this: by layering several materials of an appropriate thickness—deposited at specific intervals (let's say around 0.3B, with B representing the width of the footing), we can significantly bolster the integrity of that foundation sitting atop the vulnerable soil. It's a delicate dance of engineering, where every detail matters in ensuring the structure stands resilient against the odds. Other JGT characteristics are essential for any geotextile. Compared to its synthetic counterpart, JGT has a higher roughness coefficient and a higher along-plane drainage capability (also known as transmissivity), which enables better load transmission and exerts a better confining action on soil. The low elongation at break characteristic of woven JGT truly showcases its impressive membrane effect, outshining that of synthetic geotextiles.

Conflict of interest. Nil

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