Sustainable Energy and Environment Review
Volume 1, Issue 1, 68-79
DOI: 10.59762/seer924712041120231103144956

THE EFFECT OF SOIL REINFORCEMENT ON STRENGTH OF THE SOIL

Mahmoud Al Khazaleh
Munib & Angela Masri Faculty of Engineering, Department of Civil Engineering, Aqaba University of Technology, Jordan

Abstract
This paper explores soil reinforcement's effects on the strength of the soil. Different soil reinforcement techniques are discussed, and their effects on soil strength are analyzed. The paper further examines the benefits of soil reinforcement in terms of durability, flexibility, and permeability. Finally, the paper concludes after a discussion of potential applications of soil reinforcement in various engineering and construction projects.

Keywords: Soil Reinforcement, Geotextiles, Geotechnics, Sustainability, strength, geo-composites, Energy

1. INTRODUCTION

Soil reinforcement is a crucial method used in various engineering and construction projects to improve the strength of soil and make it more suitable for the purposes of roads, buildings, and more. This paper seeks to explore soil reinforcement's effects on soil strength, with a particular focus on the techniques used to reinforce the soil, their effects on soil strength, and the benefits of soil reinforcement. Soil reinforcement is achieved by adding materials to the soil to increase its strength, such as mesh, geotextiles, or sandbags. These materials support the soil and enhance its strength, allowing for the construction of roads and buildings on the soil. Different soil reinforcement techniques have varying effects on the strength of the soil, and the choice of technique should be carefully considered for each project. For example, mesh reinforcement increases the shear strength of the soil, allowing for greater compressive forces and increased durability, while geotextiles can increase the soil's flexibility, allowing for a smoother ride over the soil surface. In addition to improving the strength of the soil, soil reinforcement also provides other benefits. For example, it can increase the permeability of the soil, allowing water and air to pass through more easily. It can also make it easier to construct large structures on the soil, as the reinforcement materials provide a stable base on which to build. Finally, soil reinforcement can also increase the durability of the soil, allowing it to resist the erosive forces of wind and water more effectively. The potential applications of soil reinforcement are vast, and its use can be beneficial in various engineering and construction projects. From the construction of roads and buildings to the prevention of landslides and erosion, soil reinforcement can be a powerful tool to improve the strength and stability of the soil. It is also used to improve the drainage of water from the soil, which can help to reduce flooding and water damage.

1.1 Aims of Study

- To learn about the soil reinforcement
- To determine the effective methods of soil reinforcement
- To determine why soil reinforcement is necessary
- How Soil reinforcement effects engineer-

Mahmoud Al Khazaleh
Munib & Angela Masri Faculty of Engineering, Department of Civil Engineering, Aqaba University of Technology, Jordan
Email: mkhazaleh@aut.edu.jon

ing projects.

1.2 Research Question

- How does soil reinforcement affect the overall strength of the soil?
- What are the types of soil reinforcement?
- What is the most effective soil reinforcement method for increasing the soil's strength?
- What are soil reinforcement's long-term effects on the soil's stability and strength?
- How does the use of soil reinforcement techniques affect the cost of engineering projects?
- What are the potential risks associated with soil reinforcement techniques?

1.3 Background of Study

Reinforced soil has been used in construction for centuries, but its use has become more widespread in the last few decades due to advancements in materials and technology. The development of reinforced soil systems can be traced back to the late 1950s and early 1960s, when it was used extensively in the construction of embankments, retaining walls, and bridge abutments (Salimi&Ghazavi, 2021). Since then, its use has been further developed and refined by researchers in the field. An experimental study conducted by Qiming Chen of Louisiana State University and Agricultural and Mechanical College in 2017 examined the characteristics and behavior of reinforced soil foundations (Tran, Satomi & Takahashi, 2019). In addition, a comprehensive review of the various types of reinforced soil systems was published in 2012 which includes a brief history of the development of reinforced soil systems and presents a classification of the various types of systems.

1.4 Significance of Research

Soil reinforcement is an important technique for increasing the strength of the soil. The soil reinforcement technique increases the bearing capacity of soil and hence its ability to support various structures. It also helps to reduce settlements, lower the risk of liquefaction, and improve the lifespan of structures built on the soil. By reinforcing the soil, the soil becomes more resistant to shear loading or seismic forces and thus ensures that the built structure can withstand extreme conditions. Soil reinforcement also helps to reduce the rutting of road surfaces and improve the stability of embankments and slopes. The use of soil reinforcement can also help to reduce the cost of construction by reducing the amount of material that needs to be imported or purchased for construction. Finally, soil reinforcement can help to reduce the environmental impact of construction by reducing the need for excavations and soil displacement.

1.5 Summary

Soil reinforcement has become a reliable tool for maintaining soil strength and stability in various applications, such as agriculture, construction, and civil engineering. Geo textiles and geogrids are the most commonly used materials to reinforce the soil, providing it with additional strength and stability. When used in combination with other soil management practices, soil reinforcement can help ensure that the soil is strong, stable, and capable of bearing immense loads. Thus, the soil reinforcement is a key tool for maintaining soil health and ensuring that the soil can provide the necessary structure and support for a wide range of activities.

2. LITERATURE REVIEW

Soil reinforcement is a method used to increase the strength of soil and reduce its susceptibility to erosion. This method is used in many areas, such as construction, agriculture, and civil engineering. Soil reinforcement techniques use a variety of materials, such as geotextiles and geogrids, which are used to increase the bearing capacity of soil and prevent its failure. Soil reinforcement has been an important tool in agriculture, construction, and civil engineering for the past several decades. It has been found to increase the strength of soil, reduce its susceptibility to erosion, and increase its bearing capacity. Geo textiles, geogrids, and other materials are used to reinforce the soil, providing it with additional strength and stability. Geotextiles are made from synthetic or natural fibers and are typically made from polypropylene. They provide a flexible, porous, and permeable barrier between the soil and the reinforcing material, allowing the soil to breathe and allowing water to pass through. Geogrids are made from polymers and are used to provide lateral strength, holding the soil in place and reducing the risk of failure. They are often used in combination with geotextiles to provide maximum reinforcement. In addition, they can be used to increase the bearing capacity of the soil by providing a degree of lateral stability. By combining soil reinforcement techniques with other soil management practices, such as irrigation and mulching, soil strength and stability can be increased, and the risk of soil failure can be reduced.

2.1 Methods of Soil Enforcement

There are two methods of soil reinforcement, so we will discuss the method of both geotextiles and geogrids:

2.1.1 Soil Reinforcement by the Method of Geotextiles

The process of soil reinforcement using geotextiles is relatively straightforward and can be broken down into four steps:

Prepare the soil: The soil must be prepared before reinforcing it with geotextiles. This can involve removing any existing vegetation, leveling the area, and adding additional soil, sand, or gravel.
Lay the geotextile fabric: The geotextile fabric is then laid over the top of the prepared soil. It is important to ensure that the fabric is laid evenly and securely to provide an even distribution of stress across the surface.
Secure the fabric: The geotextile fabric must be secured to stop it from moving or shifting. This can be done by using staples or pins or by backfilling the area with soil or sand.
Backfill the area: Once the fabric is secured, the area can be backfilled with soil, sand, or gravel to provide additional stability and support.
Soil reinforcement using geotextiles is an effective way to enhance the strength and stability of soils. It is a relatively simple and cost-effective process that can be used in a variety of applications. Additionally, it can also provide additional protection against erosion and water infiltration.

2.1.2 Soil Reinforcement by the Method of Geogrids

Soil reinforcement by geogrids is a process of increasing the soil's ability to resist loads, deformations, and other external stresses. This method is used to improve the stability and bearing capacity of the soil for construction purposes. Here are the steps to soil reinforcement by geogrids:

Installation: Firstly, determine the best location for the geogrid reinforcement and install it accordingly. This includes excavating and preparing the soil, laying out the geogrid material in the desired location, and securing it with pins or other fasteners.
Geogrid Placement: After the geogrid material is securely in place, the next step is to place the geogrid material in the right position. The placement of the geogrid material should be such that it increases the strength and stability of the soil while still allowing for adequate drainage and moisture retention in the soil.
Compaction: Once the geogrid material is in place, the next step is to compact the soil around the geogrid material. This is done with a vibratory roller or plate compactor to ensure that the soil is firmly and evenly compacted around the geogrid material.
Embankment Fill: The last step is to fill the area around the geogrid material with the desired embankment fill material. This material should be properly compacted using a vibratory roller or plate compactor to ensure that the soil around the geogrid material has been adequately compacted.
Once all four steps are completed, the soil around the geogrid material will be reinforced, providing increased strength and stability for construction purposes.

2.2 Summary of Literature Reviews

Soil reinforcement is a widely used technique that can increase the strength and stability of soil and reduce the risk of erosion, landslides, and other soil-related problems. It can be used in a variety of applications and is often used in construction, agriculture, and civil engineering. The most common soil reinforcement techniques are geotextiles and geogrids, which are made of synthetic or natural fibers and provide a flexible, porous, and permeable barrier between the soil and the reinforcing material. Geogrids provide lateral strength, holding the soil in place and reducing the risk of failure, while geotextiles can be used to reduce seepage and increase the bearing capacity of the soil. The use of soil reinforcement techniques can lead to cost savings through reduced material and labor costs, as well as reduced construction times. However, there are potential risks associated with these techniques, such as chemical degradation, loss of strength due to age, and decreased permeability of the soil. It is important to weigh the cost and potential risks of soil reinforcement against the benefits before implementing any soil reinforcement technique.

3. METHODOLOGY

The research methodology is an essential part of the research paper because it provides the framework for author to collect and analyze the data for the study. In this research to examine the impact of soil enforcement on the strength of soil the qualitative methodology is applied. According to Johnson, Adkins & Chauvin (2020) qualitative research methodology allow researchers to conduct in-depth research on the specific context. The qualitative research allows descriptive content to deeply understand the research phenomenon. Therefore the qualitative research method is applied. Furthermore, the qualitative research effectively enable researcher to ask different questions that might not be simply explained with numbers. Therefore, human experiments are needed to deeply understand the research context. In addition, to collect the realities of certain social context and examining the important concept require researcher to gain deep understanding and knowledge. This type of methodology effectively contributes to increase research reliability and validity.

There are two different types of data collection sources such as primary and secondary data collection sources. In this research to examine the impact of soil reinforcement the secondary data was collected. The secondary data was collected from the different past published studies related to soil reinforcement. Moreover, the newspaper articles and magazine were also used to collect the secondary data for the study. According to Braun et al. (2021) one of the key benefits of the secondary data is that it is cost effective and help researcher to save time and resources. In the collection process the data was already collected and researcher does not require to invest the time, money and effort into the data collection phases of the study. In this study all data related to the soil reinforcement and its impact on soil strength are analyzed to increase the research reliability and quality. In addition, secondary data sources also provide the large amount of data and information related to the research context. Guest, Namey& Chen (2020) argued that despite the advantages of the secondary data there are certain challenges that should be considered by author while using secondary data analysis method. The researcher revealed that secondary data might lack in quality. Moreover, the source of information might be questionable particular when the data is collected from the internet.

4. ANALYSIS AND DISCUSSION

We used the Geogrids to reinforce the soil; therefore we will be analyzing the geogrids method of soil reinforcement. Geogrids are an essential tool in soil reinforcement, allowing the soil to become stronger and more durable over time. They are commonly used to construct roads, railways, walls, and other infrastructure that require strong, long-lasting soil. Geogrids are typically made from polymeric materials such as polyester or polypropylene, but can also be made from other materials such as steel or even paper. Geogrids are sheets of materials, usually polymeric materials that are laid on top of soil and connected to each other to form a lattice-like structure. The sheets are designed to have an open mesh structure, which allows for the formation of a strong, uniform network of soil particles in the soil below the geogrid. This network increases the strength of the soil, increases its resistance to erosion, and helps to reduce the amount of compaction that occurs. Geogrids are laid down in layers and then connected to each other. The layers are placed in a uniform pattern and form a strong, uniform network of soil particles in the soil below the geogrid. This network increases the strength of the soil, increases its resistance to erosion, and helps to reduce the amount of compaction that occurs. When geogrids are used to reinforce soil, they provide additional strength and stability to the soil. The network of soil particles formed by the geogrid creates an interlocking system that helps to hold the soil particles in place and prevent them from being washed away by water or wind. The geogrid also increases the bearing capacity of the soil, allowing for the construction of heavier structures.

Sustainable Energy and Environment Review
Volume 1, Issue 1
DOI: 10.59762/seer924712041120231103144956

When selecting geogrids for soil reinforcement, there are several factors to consider. The most important factor is the type of material used. Generally, the most suitable materials are polymeric materials such as polyester or polypropylene, as they are lightweight, flexible, and durable. Steel and paper can also be used, although they are more expensive than and not as durable as polymeric materials. The size of the grid openings is also important, as it will affect the strength and stability of the soil. The grid openings should be appropriate for the soil type, such as clay, sand, or gravel. The type of soil reinforcement desired is also an important factor. Geogrids can be used for slope and retaining wall reinforcement, as well as for increasing the bearing capacity of soil. The location of the geogrid should be determined. The most suitable locations are where there is a high risk of erosion, such as near rivers or slopes since the geogrid will reduce erosion. Geogrids should also be placed in areas that are prone to compaction, such as roads or driveways. By carefully considering all of these factors, an appropriate type of geogrid and size of the grid openings can be selected to best suit the soil reinforcement needs.

4.1 Impact Soil Reinforcement on Overall Strength of the Soil

Soil reinforcement is an important technique that can be used to improve the overall strength of the soil. When soil is reinforced, it is strengthened by adding either man-made or natural materials. Man-made materials often include geosynthetics such as geogrids and geotextiles, while natural materials typically include vegetation, roots, and organic matter. These materials act to bind the soil particles together and increase their strength. In addition, soil reinforcement can also improve the permeability, drainage, and stability of the soil. As a result, we can use it to reduce the effects of soil erosion, landslides, and other soil-related problems. Furthermore, soil reinforcement can also be used to decrease the settlement of structures built on the soil and increase the bearing capacity of the soil.

There is a positive and significant impact of soil reinforcement on the soil. Mistry, Shukla & Solanki (2021) mentioned that reinforcement enhance the overall strength along with the comportment capacity of the soil. Furthermore, the enlarged numbers of layers and confining pressure drive to an enhancement in the performance and effectiveness of the reinforced soil. In addition, the compaction behavior of the soil is influenced through the fiber inclusion along with the enhancement of the fiber content dry density is minimized and trivial enhancement in "optimum moisture content" OMC is observed. Kumar, Sahu& Naval (2020) found that the increase of the fiber reinforcement cause increase in tesile capability of strength of soil through an enhancement in the dry density. It is determined that due to stress-strain behavior of the soil has transformed by the brittle to ductile through an inclusion of basalt fiber.

4.2 Types of Soil Reinforcement

The most common soil reinforcement techniques are geotextiles and geogrids. Geotextiles are made of synthetic fibers woven together to form a fabric-like material. Geotextiles are used to separate soil layers, provide additional support to the soil, and reduce seepage. Geogrids are a type of geosynthetic material composed of high-strength polymer strands woven together. Geogrids are used to increase the bearing capacity of soil and reduce its susceptibility to failure. According to Bao et al. (2021) the core requirements related to reinforcement materials are considered as the stability, strength, handling, durability, soil compatibility and coefficient of friction. It is argued that different aspects such as availability and cost are also mentioned as geosynthetics which essentially known to be man made products which are supple in nature. Moreover, Abbaspour, Aflaki&Nejad (2019) found that reinforced soil is considered as the generic term which is adopted to structure constructed from placing the reinforcing components such as geotextile grid, steep strips and plastic grids in soil to offer the enhanced tensile confrontation. According to Salimi&Ghazavi (2021) another form of soil reinforcement is the sheet reinforcement. It could be developed by galvanized steel, expanded metal, fabric or steel that could not be within criteria of the grid. On the other hand, the application of geosynthetic sheet rather than steel strip is cost-efficient. In addition, it also has higher corrosion resistance as compared to strips that are commonly applied as the sheet type reinforcement are recognized as the geo-fabric. This concept is an porous fabric that is produced from synthetic material such as polythene, polymide, polyster and polypropylene and glass fiber. The range of the thickness of the sheet range is from 0.125 to 7.5mm. Aria, Kumar Shukla &Mohyeddin (2019) found that another essential type of soil reinforcement is grid reinforcement. This grid could be made from the galvanized or plan steel wire mesh. It is revealed that when the reinforcement is offered to the resist tensile force the entire geogrids could be applied. The geosyntheic materials are known as the geogrids that are made from the polymers. Furthermore, the raw materials are also applied in the geogrids that are polyester, polypropylene or polystyrene. The application of geogrids within the civil engineering is the amount that is usable land on the site could be enhanced. It allows the construction of different steep slopes or walls construction. It supports to minimize the thickness of landfill that is needed by the effective construction process.

Figure 1:Grid Soil Reinforcement Source: (Sharma, Samanta, & Sarkar, 2019).

Strip reinforcement is another form of soil reinforcement that is considered as the flexible linear elements. Moreover, their breath is higher as compared to their thickness. Generally these strips are made of metals such as chrome stainless steel, aluminum magnesium alloy and galvanized steel. There are several other forms of the strips such as polymer strips, bamboo strips glass fiber reinforced plastic strips. In addition, the thickness of these strips reinforcement might different from 3 to 9 mm however its entire breath is measures as the 40 to 120 mm.

Figure 2:Strip Soil Reinforcement Source: (Tan, Chen, Chen & Gao, 2019)

4.3 Most Effective Soil Reinforcement Method for Increasing the Soil's Strength

Soil reinforcement is an effective way to increase the strength of soil and is commonly used in areas with weak soils. The most effective soil reinforcement method is geosynthetics, such as geogrids and geocomposites, which help reinforce the soil and retain its structure and strength (Halder& Chakraborty, 2020). These materials are used to provide tensile and shear strength to the soil and to restrain its displacements. Vibro replacement stone and sand columns are widely-used soil reinforcement methods globally, as they are time-saving, cost-effective, and have limited bearing capacity. Root piles and soil nailing are also used to carry tension, shear, and compression (Wang, He, Mosallam, Li, & Xin, 2019). When planning soil reinforcement, challenges include the wide variety of soil and load variants, as well as the need to customize plans according to the soil texture and its load-bearing capacity.

The research by Abbaspour, Narani, Aflaki&Nejad (2020) found that soil reinforcement is an essential technique which is adopted to enhance overall stiffness and strength of the soil. There are several engineering techniques that are applied to increase the strength and stability of the soil such as geotextile and geogrid. Tran, Satomi & Takahashi (2019) also support the study and mentioned that soil reinforcement is an essential combination of earth fill along with reinforcing strips. They have strong ability to bear the maximum tensile strength. Therefore, it is also known as the modern technique which is applied in different project to overcome or prevent the failure of slopes of soil. It also contributes to enhance overall bearing capacity of the soil. According to Tiwari, Satyam &Puppala (2021) the core objective of soil reinforcement is to effectively perform it through placing the tensile components in the soil to improve overall strength and stability of the soil. In addition, the soil reinforcement is known as the cost effective technique that is applied to enhance overall strength of soil. Several firms effectively opted to enhance the mechanical and engineering properties of soil. Furthermore, the reinforced soil bed boosts the bearing capacity of the soil and minimizes the differential completion of soil bed. Furthermore, it also minimize overall quantity of earth fill and steeper embankment slopes support in minimize the land needed.

4.4 Soil Reinforcement's Long-Term Effects on the Soil's Stability and Strength

Soil reinforcement is an effective technique for stabilizing weak soils and improving their strength and stability in the long term. The addition of fibrous materials as geosynthetics has been shown to improve the engineering properties of the soil, such as increased strength, resistance to fracture, fatigue, and permanent deformation (Xu & Yang, 2019). Lime stabilization also enhances the engineering properties of soils, such as improved strength and higher resistance to fracture, fatigue, and permanent deformation (Lian, Peng, Zhan & Wang, 2019). Recent studies have also indicated that lime stabilization can increase swelling in soils with high sulfate contents. The swelling can be prevented if expansive soils are treated with calcium-based stabilizers, as the calcium from the stabilizer reacts with soil sulfates and alumina to form the expansive mineral ettringite (Xu & Yang, 2019).

4.5 Use of Soil Reinforcement Techniques Affect the Cost of Engineering Projects

By reinforcing the soil, engineers can reduce the cost of projects by reducing the amount of material and labor needed. The use of soil techniques can also reduce construction times, as the soil is already more stable and durable before construction begins. Soil reinforcement techniques are often used for large-scale projects, such as foundations for bridges and buildings. By reinforcing the soil with layers of synthetic material, the soil can be made to bear heavier loads, allowing for the construction of taller and/or larger structures. This reduces the amount of material needed and the amount of labor required, leading to cost savings. Soil reinforcement techniques can also be used for smaller-scale projects, such as the installation of retaining walls and the strengthening of slopes. In these cases, soil reinforcement can reduce the amount of material and labor required, leading to cost savings. The use of soil reinforcement techniques can also reduce construction times, as the soil is already more stable and durable before construction begins.

4.6 Potential Risks Associated With Soil Reinforcement Techniques

The most common risks are related to the materials used in soil reinforcement. If using synthetic materials such as geotextiles, the risk of failure due to chemical degradation or environmental conditions is higher than with traditional reinforcement methods. Additionally, there may be a risk of the material losing its strength due to age, mechanical damage, or incorrect installation. Another risk is that the soil reinforcement technique may not be effective in the long term, as the soil may slowly shift or move and cause instability in the structure. In addition, there is the risk that the soil reinforcement technique may lead to a decrease in the amount of permeability of the soil, which can lead to waterlogging and flooding. Finally, there are potential risks associated with the cost of soil reinforcement. Although the initial cost may be high, the long-term benefits may not outweigh the cost of the materials. Additionally, the soil reinforcement is labor-intensive and requires specialized skills and equipment, which can add to the cost. Singh, Trivedi & Shukla (2019) conducted the research to determine the interaction among the different grid reinforcement and cohesive frictional soil. The author applied 52 large scale pullouts along with 26 large scale direct shear tests. The increase scale direct shear outcomes indicated that the shear stresses and interfaces the grid and soul reinforcement can increase to the direct shear resistance of the soil. In addition, the shear strength parameters achieved by the large-scale direct shear were determined to the smaller as compared to the outcome of the Triaxial UU tests. On the other hand, Xiong, Xing & Li (2019) examined the impact on particle size on the geosythetic structure. They essential concluded that the enhancement in the soil-geogrid interface the shear resistance is determined when the soil included the significant percentage of particles through the sizes that are slightly more that the thickness of the geogrid bearing members, however smaller as compared to the geogrid apertures. The research by Tiwari, Satyam &Puppala (2021) revealed that pressure-settlement characteristics of the rectangular footings towards the reinforced sand. In their research, they have applied the model rest outcomes that have been conducted through a research by on square footing through dimensions of 0.175 into 0.175 m which rests on the sand. The model test proposed by Liu, Lv, Yu, & Wu (2020) highlighted that square footing of around 0.62 into 0.62 m in size resting on the sand reinforced with the Tensar SS20 geogrids. In contrast, the work proposed by Yang & Chen (2019) found that confining impact of the reinforcement offered in the soil in various layers was included in the analysis through considering the equivalent stresses proposed because of the friction at the soil-reinforcement interface. The author found that the value of settlement might be read directly through the pressure-settlement curves for the provided pressure intensity. Thus, the rectangular footing which resting on the reinforced sand that could be proportioned satisfying shear failure and settlement criteria. In this regard, Masi, Segoni&Tofani (2021) conducted or performed the experimental work on the layered sand soil. They have applied various reinforcement layers to effectively examine the impact of the reinforcement towards the bearing capacity on strip which footing around 0.15 into 1.19 m resting towards the top strong sand layer through an underlying weak sand layer. In this regard, the research also concluded replacing the top layer of soil through a well graded soil is essential or beneficial because of the mobilization of soil reinforcement frictional resistance would increase. In addition, Syed &GuhaRay (2020) revealed the replacement of 1 B foundation width on the top layer through wall graded sand layers helped increase overall bearing capacity up to 3 to 4 times. According to Tran, Satomi & Takahashi (2019) the soil reinforcement techniques are mainly applied to enhance the engineering properties of the soils within the geotechnical engineering application. For that reason, different synthetic and natural fibers have been managed to appeal the attention of the geotechnical engineers due to an alternative reinforcement technique for traditional stabilization methods because of the low cost, sufficient strength and easy availability. The objective of this research was to determine the influence of parameters such as physical, fiber type and mechanical properties for fiber, fiber length, fiber quantity and fiber surface roughness on the engineering properties of various forms of soil reinforcement. In addition, the research also covers the information related to the impacts of water within soil matrix towards the behavior of natural fiber along with the recommended treatment along with the mechanical behavior related to the fiber-soil composite. According to Xiong, Xing & Li (2019) the application of the soil reinforcement has been broadly determined as the alternative towards the conventional design of several geotechnical systems. It essentially comprise of the placement of reinforcement inclusion such as planer geosynthetics among the compacted soil layers to offer the tensile strength which support to provide strength on the soil mass. The author also found that these layers often intercept the potential shear failure surfaces which tend to develop within the soil structure producing tensile forces which offer stability to the otherwise unstable soil mass. Furthermore, the conventional design of these reinforced soil systems emphasize on determination of the entire tensile capacity related to the reinforcing inclusion although the designs are mainly insensitive towards the distribution of the inclusion in the soil structure such as reinforcement vertical spacing. There are several potential studies that pointed about the relevance of interaction which might create among the reinforcement layers, rendering the behavior which has often been defined as the composite material. These types of behavior are often mentioned to have occurred within system where the reinforcement spacing is highly small or limited. Several wide researches have been established to characterize the interaction and linked loading mechanisms which can occur at the actual soil reinforcement interface. However, limited researches have been proposed to categories the lead transfer which occurs beyond the interface. The current research indicated that the load transfer beyond the actual interface can effectively manage or control the interaction among the neighboring reinforcement layers which could increase with the increasing transferred load. The connection among the reinforcements along with the surrounding soil and interaction with reinforcement layers could play the essential role in entire mechanical response of the reinforced. Ng, Leung & Ni (2019) mentioned that the constructive soil reinforcement is an essential technique which comprised of the soil structure with vertical face. Hence, the facings are often based on the prefabricated concrete or steel panels that are aligned together with the interlocking mechanism. Furthermore, the soil is effectively applied as the backfill in the situations in which the soil is granular with low as compared to the 15% of fines which support the development of high friction among the reinforcement and soil. This is mainly applied for reinforcement as steel strips because they have high tensile strength with low extensibility. This method is effectively adopted as the technique in which the reinforcement process is kept at the similar time as the remolded and imported soil. These techniques are often known as the bottom-up process because it comprise of the placement of the fill and reinforcement at the same time. It also covers the structures such as soil embankments and bridge abutments. The reinforcement needed to conduct the process which comprise of the type of mats, grids and strips. There are several challenges related to the plans for the soil reinforcement that are often personalized based on properties of soil such as its capacity, load bearing and texture. Moreover, there are broad range of load variations and soil therefore different challenges which occurs which affect the soil such as weak foundation, retaining walls, subgrade stabilizing etc. Tiwari, Satyam &Puppala (2021) found that embankments on weak foundation is one of the leading challenge which affect the soil reinforcement. The weaker foundations such as airports near to the sandy ground require reinforce of the soil and stabilize it. On the other hand, Rezvani (2020) found that geotextiles are effective aligned through the various forms of wall applications such as on-site fills to effectively reinforce the supporting walls. Moreover, the geotextile offers the alternative to the traditional methods which covers cast-in-place concrete structure for retaining the walls. On the other hand, Tran, Satomi & Takahashi (2019) revealed that subgrade stabilizing another challenge of soil reinforcement. For example for organic and soft solid the tensile strength is minimum or low. Moreover, the cost needed for the traditional land filling could be around 50% high as compared to the cost of soil reinforcement through a geotextiles. It could be effectively applied to disperse the load equally within the soil and minimize the displacement of the different small or limited soil particles. The reinforcement of base course is another challenge which affects the soil reinforcement. The study mentioned that through enhancing the tensile strength of granular base course material, the entire load bearing capacity within soft soil is enhanced. The application of geotextiles enhances the tensile strength through enhancing its capacity of load bearing at the granular base structure which is also used for the grid. The steeping slopes also affect the soil enforcement process. It essentially covers different layers of geotextiles which is kept methodically on the land for steepen the soil slopes. This effectively meets the entire increase strength of tensile without the threat of soils rotating or sliding. The application of soil reinforcement is based on the slope failure repairs. Masi, Segoni&Tofani (2021) mentioned that several small and large landslides and failures of different natural slope mainly occur in the regions in which the environment requires the call for repair of the slope for the original geometry. This might be because of the economical or technical tourists' attraction. It has been found that the geogrids effectively enable few soil of landslide to reinvent the slope and therefore offering the solution rather than importing the soil through the better mechanical categories that will have limited cost implications. The core benefit of geogrids reinforced the slope which could be easily vegetated to meet the seamless integration in the surrounding environment. The research by Xiong, Xing & Li (2019) bridge abutments and wing walls are mainly earth retaining structures which encourage the heaviest loads. Moreover, beside the horizontal loads and high vertical adopted from the bridge deck and dynamic loads by the traffic and seismic load which challenge the entire design. Soft soils, high water table and environment affect contributes to the additional issues. These applications such as geogrid reinforced the soil structures offer the strong and flexible retaining structures. Moreover, the bridge abutments along with wing walls could be developed with intent to resist various anticipated loads related to security and poor soil quality. Liu, Lv, Yu, & Wu (2020) mentioned that another soil reinforcement application is related to road and railway embankments. They are often large and high structure that need sizeable amount of land and fill soil. The cost of transporting this form of soil by the quarries could be substantial and therefore few alternatives and needed such as applying low quality soil fill or stepper slopes.

5. CONCLUSION

The research paper concluded that the soil reinforcement techniques are mainly applied to enhance the engineering properties of the soils within the geotechnical engineering application. For that reason, different synthetic and natural fibers have been managed to appeal the attention of the geotechnical engineers due to an alternative reinforcement technique for traditional stabilization methods because of the low cost, sufficient strength and easy availability. The research also concluded that the soil reinforcement is known as the cost effective technique that is applied to enhance overall strength of soil. Several firms effectively opted to enhance the mechanical and engineering properties of soil. Furthermore, the reinforced soil bed boosts the bearing capacity of the soil and minimizes the differential completion of soil bed.

REFERENCES

Abbaspour, M., Aflaki, E., &Nejad, F. M. (2019). Reuse of waste tire textile fibers as soil reinforcement. Journal of cleaner production, 207, 1059-1071. https://doi.org/10.1016/j.jclepro.2018.09.253

Abbaspour, M., Narani, S. S., Aflaki, E., &Nejad, F. M. (2020). Behavior of a subgrade soil reinforced by waste tire textile fibers under static and cyclic loading. Journal of Materials in Civil Engineering, 32(8), 04020208. https://doi.org/10.1061/(ASCE)MT.1943-5533.0003279

Aria, S., Kumar Shukla, S., &Mohyeddin, A. (2019). Numerical investigation of wraparound geotextile reinforcement technique for strengthening foundation soil. International Journal of Geomechanics, 19(4), 04019003. https://doi.org/10.1061/(ASCE)GM.1943-5622.0001361

Bao, X., Huang, Y., Jin, Z., Xiao, X., Tang, W., Cui, H., & Chen, X. (2021). Experimental investigation on mechanical properties of clay soil reinforced with carbon fiber. Construction and Building Materials, 280, 122517. https://doi.org/10.1016/j.conbuildmat.2021.122517

Braun, V., Clarke, V., Boulton, E., Davey, L., &McEvoy, C. (2021). The online survey as a qualitative research tool. International journal of social research methodology, 24(6), 641-654. https://doi.org/10.1080/13645579.2020.1805550

Guest, G., Namey, E., & Chen, M. (2020). A simple method to assess and report thematic saturation in qualitative research. PloS one, 15(5), e0232076. https://doi.org/10.1371/journal.pone.0232076

Halder, K., & Chakraborty, D. (2020). Influence of soil spatial variability on the response of strip footing on geocell-reinforced slope. Computers and Geotechnics, 122, 103533. https://doi.org/10.1016/j.compgeo.2020.103533

Johnson, J. L., Adkins, D., & Chauvin, S. (2020). A review of the quality indicators of rigor in qualitative research. American journal of pharmaceutical education, 84(1). https://doi.org/10.5688/ajpe7120

Kumar, S., Sahu, A. K., & Naval, S. (2020). Influence of jute fiber on CBR value of expansive soil. Civil Engineering Journal, 6(6), 1180-1194. https://doi.org/10.28991/cej-2020-03091539

Lian, B., Peng, J., Zhan, H., & Wang, X. (2019). Mechanical response of root-reinforced loess with various water contents. Soil and Tillage Research, 193, 85-94. https://doi.org/10.1016/j.still.2019.05.025

Liu, C., Lv, Y., Yu, X., & Wu, X. (2020). Effects of freeze-thaw cycles on the unconfined compressive strength of straw fiber-reinforced soil. Geotextiles and Geomembranes, 48(4), 581-590. https://doi.org/10.1016/j.geotexmem.2020.03.004

Masi, E. B., Segoni, S., &Tofani, V. (2021). Root reinforcement in slope stability models: a review. Geosciences, 11(5), 212. https://doi.org/10.3390/geosciences11050212

Mistry, M. K., Shukla, S. J., & Solanki, C. H. (2021). Reuse of waste tyre products as a soil reinforcing material: a critical review. Environmental Science and Pollution Research, 28(20), 24940-24971. https://doi.org/10.1007/s11356-021-13522-4

Ng, C. W. W., Leung, A., & Ni, J. (2019). Plant-soil slope interaction. CRC Press. https://doi.org/10.1201/9781351052382

Rezvani, R. (2020). Shearing response of geotextile-reinforced calcareous soils using monotonic triaxial tests. Marine Georesources&Geotechnology, 38(2), 238-249. https://doi.org/10.1080/1064119X.2019.1566936

Salimi, K., &Ghazavi, M. (2021). Soil reinforcement and slope stabilisation using recycled waste plastic sheets. Geomechanics and Geoengineering, 16(6), 497-508. https://doi.org/10.1080/17486025.2019.1683620

Sharma, M., Samanta, M., & Sarkar, S. (2019). Soil nailing: an effective slope stabilization technique. Landslides: Theory, practice and modelling, 173-199. https://doi.org/10.1007/978-3-319-77377-3_9

Singh, M., Trivedi, A., & Shukla, S. K. (2019). Strength enhancement of the subgrade soil of unpaved road with geosynthetic reinforcement layers. Transportation Geotechnics, 19, 54-60. https://doi.org/10.1016/j.trgeo.2019.01.007

Syed, M., &GuhaRay, A. (2020). Effect of fiber reinforcement on mechanical behavior of alkali-activated binder-treated expansive soil: reliability-based approach. International Journal of Geomechanics, 20(12), 04020225. https://doi.org/10.1061/(ASCE)GM.1943-5622.0001871

Tan, H., Chen, F., Chen, J., & Gao, Y. (2019). Direct shear tests of shear strength of soils reinforced by geomats and plant roots. Geotextiles and Geomembranes, 47(6), 780-791. https://doi.org/10.1016/j.geotexmem.2019.103491

Tiwari, N., Satyam, N., &Puppala, A. J. (2021). Strength and durability assessment of expansive soil stabilized with recycled ash and natural fibers. Transportation Geotechnics, 29, 100556. https://doi.org/10.1016/j.trgeo.2021.100556

Tran, K. Q., Satomi, T., & Takahashi, H. (2019). Tensile behaviors of natural fiber and cement reinforced soil subjected to direct tensile test. Journal of Building Engineering, 24, 100748. https://doi.org/10.1016/j.jobe.2019.100748

Wang, X., He, J., Mosallam, A. S., Li, C., & Xin, H. (2019). The effects of fiber length and volume on material properties and crack resistance of basalt fiber reinforced concrete (BFRC). Advances in Materials Science and Engineering, 2019, 1-17. https://doi.org/10.1155/2019/7520549

Xiong, F., Xing, H., & Li, H. (2019). Experimental study on the effects of multiple corrosive ion coexistence on soil-cement characteristics. Soils and Foundations, 59(2), 398-406. https://doi.org/10.1016/j.sandf.2018.12.001

Xu, J. S., & Yang, X. L. (2019). Seismic stability of 3D soil slope reinforced by geosynthetic with nonlinear failure criterion. Soil Dynamics and Earthquake Engineering, 118, 86-97. https://doi.org/10.1016/j.soildyn.2018.12.019

Yang, X. L., & Chen, J. H. (2019). Factor of safety of geosynthetic-reinforced slope in unsaturated soils. International Journal of Geomechanics, 19(6), 04019041. https://doi.org/10.1061/(ASCE)GM.1943-5622.0001399