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Applications of Geo-Textiles for the stabilization of soil: A Review

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Abstract:

Soil serves as a support for the construction and effectively distributes load. If the soil is unable to bear load effectively, the structure fails in a variety of ways, including settlement, fractures, and other types of structural collapse. If soil is not properly stable, it sometimes creates a lot of problems for construction engineers, mostly due to the lower bearing capacity of the soil and its high compressibility. Therefore, to increase the load bearing capacity and engineering properties of subsoil (known as Soil Stabilization), a wide range of methods and reinforcing materials are available, such as: geo-textile sheets, geo-grid, metal strips, bar mats, etc. The strength and stability of soil mass can be improved and increased with the help of the stabilization process, and the settlement of structures built on it is reduced. Geo-textile (Geo-synthetic) is a reinforcing material made of thin permeable sheets of synthetic fibres that are widely used in modern engineering practice to strengthen foundations, slopes, crushed stone columns, road pavements, etc. From the various studies done by many researchers in recent years, it is determined that the geo-textile used in all the projects or research work has a significant impact on the properties of the soil. In this paper, before and after putting in the geo-textile, dry density, shear strength, permeability, and CBR values have been compared, and an effort has been made to collect information about soil stabilization using geo-textiles, which includes a brief summary of their procedure and their applications and identifies the different areas that need further attention or improvement.

Keywords: Soil Stabilization, Geo-textile, Reinforcement, Sub-grade, Geotechnical tests.

Introduction

In olden times, a substantial role in the development of structural engineering was made possible only by parallel developments in building material technology. For the construction of large and elaborate structures, man initially used wood, then limestone, and then cement concrete, reinforced cement concrete, and more recently, pre-stressed reinforced concrete. Whereas, soil and rock are commonly used as geotechnical materials. Whereas, soil and rock are commonly used as geotechnical materials. It is difficult to expect a similar development in

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geotechnical construction. In geotechnical engineering, a variety of materials are taken to improve the quality of the soil, one of which is geosynthetics (Geotextiles). The use of geotextiles has been described through this research paper. Use of geotextiles increased the tensile resistance capacity of soils. Due to this, the load-carrying capacity of the soil and stability of the soil increased. [1]

The soil which has contained silt and clay particles exhibits significant distress signs, including shrinkage and strength loss during the rainy seasons throughout the summer. Because of its expansive behavior, black cotton soil loses its strength during the rainy season. The following are some of the issues with soil expansion (N.B.O. 1962).

When soil is saturated, expansive soils exhibit high plasticity and are compressible. These soils have a high dry strength but become mushy after being saturated. Filling pores and cracks with water accelerates the softening process, reducing shear strength and resulting in limited bearing capacity.

Differential heaving of structures created in the dry season as an outcome of soil swelling throughout the subsequent wet season. Swelling restrictions create swelling pressure, which makes the structures unstable. As a result of the formation of fractures, structures supported on soil lift up. During the dry season, structures constructed at the end of the rainy seasons, when high natural water content, display shrinkage cracks and settlements. Through skin friction, shrinkage causes downward pressure on the foundation, increasing the foundation pressure. [2]

Because of these factors, expansive soils must be treated before being used as an engineering material. Soil modification and soil stabilization are the two processes that these treatments are grouped into. The technique of blending and combining things with soils to enhance the specific features of soils is termed "soil stabilization. Blending soils with commercially existing admixtures which affect the texture, stage, or plasticity, or function as the binder of soil cementation, may be part of the process (IRC: SP: 89-2010). Soil modification is a stabilizing procedure by which a change in one or more soil properties occurs without a considerable gain in soil strength or durability.

Various soil stabilization and modification procedures can modify soil qualities such as strength of the soil, compressibility features, its workability, swelling potential, and tendencies to volume change.

Thermal, mechanical, chemical, and electrical methods are used to achieve stabilization. Because thermal and electrical energy are rarely used, there is less information available on them. The use of mechanical energy to densify soil is known as mechanical stabilization or compaction. Densification causes air to be evacuated from soil cavities without any significant changes in the moisture content. This technique can be used to stabilize soils with low cohesion where the compaction energy can promote particle interlocking and the rearrangement. However, if soil is exposed to considerable moistness fluctuations, then procedures are ineffective. Efficiency of compaction might be reduced if the fine content of the soil (fraction less than 75 micron) increases. Because of interparticle connection and rearrangement during compaction, this is the case. For the fine-grained soil to change the physio-chemical properties, chemical

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stabilization, rather than densification, is a more effective way. Chemical stabilization of the non-cohesive and coarse-grain soil by more than 50% by weight at a grain size greater than 75 microns can be profitable if a significant stabilization response is accomplished in the soil (Dallas and Syam 2009).[2].

Therefore, Geotextiles are expected to be cost-effective, long-lasting, and simple to use. Geotextiles are becoming increasingly important in geotechnical engineering. In this review paper a brief summary of the research work done on soil stabilization using geo-textile.

Geo-synthetic materials are made up of synthetic fiber and polymers used as geotextiles such as polypropylene, polyethylene terephthalate, polyethylene, polyamide etc. Synthetic fibres are utilised in contact with soil, rock, or other geotechnical materials to improve soil engineering properties. Geo-textile, geo-grid, geo-cell, geo-net, geo-membrane, erosion control mat, geo-synthetic clay liner, and geo-composite are some of the most common geo-synthetics [1]. The most extensively utilized geo-synthetics are geo-textiles. The nylon bags filled with sand employed in the Dutch Delta Works in 1956 can be regarded as the first known application of geo-textiles.

For the past 60 years, geotextiles have been frequently utilized in geotechnical engineering. Geotextiles can help with separation, filtration, drainage, reinforcement and stabilization, barrier, and erosion protection in geotechnical engineering. [3].

Every year, more than 1.4 billion square metres of geotextiles are utilized, and this tendency is expected to continue. Approximately 98 percent of geotextiles are made of non-biodegradable polymers from the polyester, polyolefin, or polyamide families. Long-term use of geo-textiles may result in the breakup of synthetic polymer, results in the form of accumulation of microplastics in the surrounding environment, due to a variety of environmental conditions such as friction, wind, moisture, and UV radiation.

Furthermore, when geotextiles are used in geotechnical engineering, they raises the performance requirements of geotextiles [3].

As a result, geo-textiles are thought to be cost-effective, long-lasting, and simple to utilize. Geotextiles are becoming increasingly important in the field of geotechnical engineering. The main objective of paper is to deliver a quick overview of the research on soil stabilization using geotextiles which have been done by many researchers.

Material and Methodology:

Materials and methodology for ‘Application of Geotextiles for the stabilization of soil’ used by different researchers are given below-

Talal o. **Al-Refeai (1999)** worked to understand the resilient behavior of a weak subgrade soil with the geotextile reinforcement which is laid on the soil subgrade. The effect of deviator stress and confining stress on the resilient behavior of a base subgrade arrangement provided with a nonwoven geotextile reinforcement layer has received special attention. They studied the influence of nonwoven geo-textile on the resilient and plastic behavior of a sub-grade geo-textile base system by conducting a series of cyclic triaxial tests on two different soils (coarse sand as a base material and clayey silty sand as a sub-grade material) [5].

E.A. Subaida et al. (2010) conducted an experimental investigation to determine the benefits of using fabricated coir geotextiles in place of reinforcing material in the pavement section. A robust circular plate in acres was used to put on monotonic and consistent loads on both the reinforced laboratory road sections and unreinforced road sections. The impacts of estimated geotextile position and stiffness were examined with the help of using dual base courses and 2 types of woven coir geotextiles [12].

Abhijith R.P. (2015) The natural coir fibers' importance on approved roads is presented through an experimental study. The coir fibres provide a reinforcing action on the subgrade soils. Coir fibre is a natural material derived from coconut husk. Coir fibre is commonly found in many places in India. Use of coir fibre improves the strength of sub grade soil. Coir fibres of varying lengths from 0.5 to 3 cm and 2 to 8 per cent of the total soil weight are mixed and a correlation is made by the CBR test. As a result, the introduction of soil at two-thirds of the depth appears to be more effective. Reinforcement action is necessary during the initial phase; thereafter, reinforcement action is achieved by consolidation of subgrade soil [13].

Sugandini and Madhuri (2017) worked on soil geo-synthetics (including geo-textile) interaction properties for four types of soils (Red laterite, Marine clay, Black Cotton Soil, and Sandy soils) were used with the geo-composite reinforcing materials and CBR tests were conducted to find out the density of the soil samples and the mechanical strength of the sub-grade soil. The main objective of the work is to study the effect of the strength of the soil after the application of geo-synthetics [8].

D.A. Ogundare et al. (2018) explored the use of non-woven geotextiles in sub-grade material as a road building reinforcement. They assessed two soil samples for sub-grade suitability based on their geotechnical qualities. According to the AASHTO, virgin soil samples A and B, which are classified as A – 7 – 5 and A – 7 – 6, respectively, are weak sub-grade materials.

Compaction experiments were conducted by using a hard metal mould with a height of 175 mm and an interior diameter of 150 mm for this experiment. Soil samples were compacted into three layers, each with 25 blows of a 2.5 kg rammer falling from a height of 310 mm.

The CBR tests were carried out in a single layer of soil (compressed soil) in unsoaked conditions without reinforcement and placed at a depth h/4 from the top surface and base surfaces of the soil sample in a mould with reinforced non-woven geotextiles. Load values corresponding to the results were noted at 0.25, 0.5, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, 7.5 and 8.00 (all values in millimetre). [4].

Vivek et al. (2018) stabilized the soil by using coir geo-textile and described its use, which provides knowledge about the enhancement of soil properties with the results of CBR and shear tests carried out before and after the treatment. [7].

Prasad and Satyanarayana (2018) In his study examined, to improve the soft marine clay, silica-manganese slag mixed with sand was used as stone column material, and geo-textile material was employed to support the stone columns as reinforcement. This geo-textile was cut into circular discs and placed horizontally within the stone column at a 50mm interval (equivalent to the stone column's diameter "D").

Marine clay, Silica-Manganese slag, Sand and Geo-textile were used in his study. For the preparation of the geo-textile reinforced stone column, after the clay bed was prepared to a depth of 100mm at the bottom, a PVC pipe of 5cm in outer diameter and 1mm thick was located at the centre of the tank, and the clay bed was prepared to the outside of the pipe in 50mm layers up to the remaining height of 200mm, which is prepared similar to the procedure used to prepare the plain stone column. The reinforced stone column was constructed for different reinforcement lengths and was prepared in two stages, i.e., the unreinforced and reinforced portions. To construct the fully reinforced (D) stone columns, the geo-textile discs were placed at specified intervals of "D" within the stone column trial and the compaction was done similar to the unreinforced column. To construct the partially reinforced stone column (D/2D/3D), the bottom unreinforced portion was constructed similar to the unreinforced portion and the upper reinforced portion.

After completion of the stone column, it was kept for 24 hours for moisture equalization and to improve the bonding between the aggregates and the clay bed. After the load tests were conducted for the clay bed, unreinforced and reinforced stone columns, load settlement graphs were drawn and the ultimate load and corresponding settlements were determined by drawing double tangent method [9].

G.G. Janakiraman et al. (2019) focused on better understanding of natural and artificial geo-textiles for strengthening of subgrade soil and evaluated the effect of reinforcement of geo-textiles on subgrade soil. For this, **Tanvi Singh et. al. (2020)** examined the strength enhancement with the help of experimental investigation. The main objective of their investigation was to decrease the pavement thickness and to rise the strength of pavement structures by using geo-textile as reinforcement material and in their experiments they also included the study on the effect of type of geo-textile used for reinforcement, effect of position of reinforcement layer, effect of number of layer of reinforcement, prediction of CBR values using ANN and M5P, Prediction for woven geo-textile, prediction for non-woven geo-textile [6].

Results and Discussions: Based on the above materials and methodology

they took five dissimilar geo-textiles (composite geo-textile, Geo-bag geo-textile, Hot Bound geo-textile, Coir geo-textile, non-Woven geo-textile) and the load-penetration performance of granular soil reinforced with geotextiles was examined in the laboratory by the California Bearing Ratio test. Granular soil specimens of various gradings are selected and tested for lack of reinforcement.

A field CBR test was conducted on soil filled with a ground grid in test pits. Test pits of a size of 0.5 m × 0.5 m × 0.5 m were excavated and filled with moisture-retaining soils having moisture content and density. In order to ensure the density and moisture after filling, the core cutter test is carried out on the loaded soil.

The field density and moisture content have been measured. The soil filling with and without geogrid was subjected to a CBR test. For all testing on geo-grid reinforced soil beds, a single layer of geo-grid is laid at the mid-height of the soil in the pit. The experiment is repeated with different geo-grids and soil fill levels. The load is applied via the response loading technique, which is aided by the truck [11].

used by researchers, they came to results as given below-

Talal o. Al-Refeai (1999) according to the results of the experimental investigations, the resilient modulus of the sub-grade geo-textile base system increases as the confining stress grows and drops as the deviator stress increases. In contrast to the very little influence of geo-textile inclusion on k3, the influence of geo-textile on k2 is significant, implying that the relative sensitivity of the sub-grade geo-textile-base system to changes in deviator stress is lower than that of the sub-grade base system.

Behavior of Geo-textile Reinforced Sand on Weak Sub-grade231. Because of confining and deviator stresses, the

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AASHTO models (equations 1 and 2) may be unable to predict the change in resilient modulus of sub-grade geotextile-base systems. The addition of nonwoven geotextile to the sub-grade geotextile base system resulted in just a minor increase in the system's resilience modulus of around 14%. The presence of geotextile improved the plastic behaviour of the sub-grade geotextile-base system and reduced permanent deformation by almost 50%.

The findings indicate that the use of the geotextile had no significant effect on the resilient modulus (increase of only 14 percent). Permanent deformation, on the other hand, was significantly reduced (by 50%). [5].

E.A. Subaida et al (2010) By use of coir geotextiles improved the bearing capacity of thin sections, according to E. A. Subaida et al. The load-carrying capability of geotextile applied at the interface of the subgrade and base course was significantly increased during major deformations. When coir geo-textile placed within the base path at all stages of deformations, there was a significant increase in bearing capacity. The coir geotextile was developed to be installed one-third of the plate diameter under the surface in the base course. [12]

Abhijith R.P (2015) The results of Abhijith R.P (2015) concluded that introducing Geo-textiles at a depth of two- thirds from the bottom was more successful. The initial reinforcing activity is required, and later reinforcing action is produced through the consolidation of subgrade soil. [13]

D.A. Ogundare et. al. (2018) It is observed that when the two soil samples were reinforced with non-woven geo-textile, there was an increase in their CBR values in unsoaked condition (15% and 21%) than when equated with their CBR values (4% and 7%) without reinforcement which shows that the soil sample reinforced with nonwoven geo-textile are suitable for sub-grade as established under the specification of the Federal Ministry of Works (1997) criteria for sub-grade soils.

Summary of preliminary test results: -

Classification (BIS)	**G M**	**G C**	**G W**
Liquid-limit (%)	35.50	43.50	23.00
Plastic-limit (%)	20.20	29.40	-
Plasticity-index (%)	15.30	14.10	-
Specific-gravity (g)	2.70	2.63	1.98

Table (1)

CBR values under Soaked Condition: -

Soil samples	**Without nonwoven geotextile 2.5mm**	**5.0 mm**	**C B R value (%)**	**With nonwoven geotextile 2.5mm**	**5.0 mm**	**C B R value (%)**
Samples A	2.8	3.2	3.2	9.6	9.7	10.0
Samples B	5.2	6.0	6.0	15.8	13.8	16.0
Samples C	1.4	1.5	2.0	2.8	2.6	3.0

Table (2)

According to their experimental data, the application of non-woven geo-textile at various depths, as measured by the California Bearing Ratio (CBR), generally increases the strength of the sub-grade

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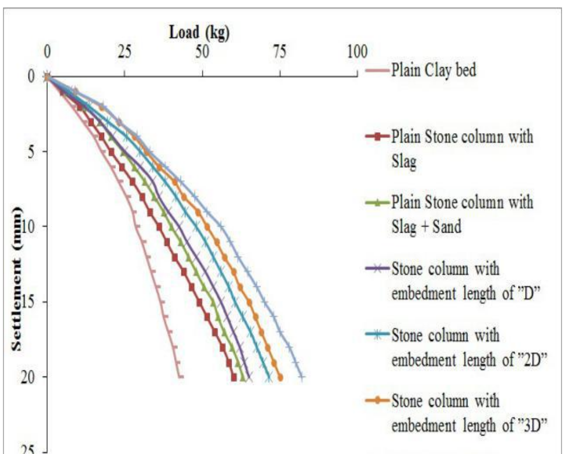
soil, irrespective of the level at which the non-woven geo-textile is installed within the thickness of the sub-grade.

Prasad and Satyanarayana (2018) from their study, following conclusions were derived-

Load carrying capacity of the soft clay can be increased by introducing the stone column and also by adding the sand to the stone column by minimizing the voids between the aggregates. Load carrying capacities are increased to 32% and 43% by improving the soil with the Slag column and Slag Sand column respectively. Stone column performance can be increased by introducing the lateral geotextile discs within the column.

Load carrying capacity can be increased by increasing the embedment length of reinforcement.

Settlements can be reduced by improving the soil with stone column and also with the reinforcement length. Settlement of the clay bed was reduced from 10mm to 4.0mm by reinforcing the soil with the reinforcement length of4D. Bulging of the stone column can be reduced by introducing the reinforcement and also with the reinforcement length. Bulging of the plain stone column was reduced from 7.5mm to 5.5mm by reinforcing with geo-textile to a length of4D. The maximum bulging for the unreinforced stone column was found at the middle of the column. Whereas for the reinforced columns, the maximum bulging found below the end of the reinforcement. The results indicate that the soft soil can be improved with the stone column and can be further stabilized with the geo-textile reinforcement [9].

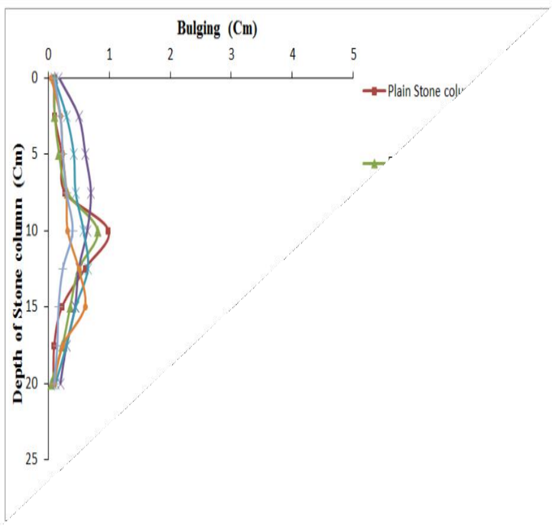


Graph-1 (Source- Prasad and Satyanarayana, 2018)

BULGING ANALYSIS OF STONE COLUMNS

After the load testing, the slag aggregates were removed, and the hole created in the clay bed was filled with plaster of Paris paste and allowed to set for one day before the surrounding clay was removed to get the deformed shape. The bulging behaviour of the columns was investigated after measuring deformations at 2.5cm intervals throughout the length of the stone columns. The column's depth vs bulging is displayed on a graph.

Graph 2 depicts the bulging curves of unreinforced and reinforced stone columns with different reinforcing depths. The core of the stone columns that were not reinforced had the largest bulging of 10 mm. The maximum bulging of the stone column was reduced to 8.1 mm using slag+sand. The addition of reinforcement lowered this even more, resulting in maximum bulging of 7.0 mm, 6.5 mm, 6.0 mm, and 4.0 mm for reinforcement lengths of D, 2D, 3D, and 4D, respectively.



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Graph-2 (Source- Prasad and Satyanarayana, 2018)

G.G. Janakiraman et. al. (2019) from their study, following conclusions were derived-

Soil that has been reinforced with geo-synthetics (natural or synthetic geotextiles) becomes stronger and stiffer than soil that has not been reinforced. Placing geotextile material in soil enhances the soil's bearing ability and load carrying capacity, extending the pavement's service life. Experimental tests revealed a significant increase in subgrade strength, verifying the theoretical aspects. When geo-synthetics are utilized in pavements, they provide a variety of purposes such as strengthening, separation, drainage, and filtering. Grain size analysis, Atterberg, compaction, and the California bearing ratio test were all recognized as geotechnical tests. To determine the strength of the soil, CBR tests were carried out by inserting geo-grids at varied depths and in a single layer under unsoaked conditions. As a result of incorporating geo-grids into the soil, the strength of the subgrade has also been significantly increased. It was discovered that geo-grids located 3/5 of the way from the base had a higher CBR value than those placed 2/5 and 4/5 of the way from the base. As the number of layers of geo-grids increases, changes in the behavior of the soil under unsoaked conditions emerge. It has showed a significant effect of improvement as a subgrade stabilizer. It has a quick preservation time, is corrosion resistant, and extends the road pavement's service life. The results of these studies show that adding geotextile to reinforced granular soils raises the bearing ratio. As a result, geotextile should be used as a more current approach of enhancing road construction on weak subgrade materials.[11].

Tanvi Singh et. al. (2020) were examined the effect of reinforcing woven and non-woven geo- textile at different depth of reinforcement in single and double layer in terms of CBR value in their research work. Further for prediction of CBR, ANN and M5P modeling approaches were used. Vital outcomes of their research are listed below: Strength of sub-grade soil was enhancing upon reinforcement with both woven and non- woven geo- textile. Rise in strength with reference to parent soil was noticed from 19.79% to 188.23% depending on the position of reinforcement, type of geo-textile laid and number of layers of reinforcement.

Sub-grade soil reinforced with woven geo-textile gives better result when reinforced with to nonwoven geo- textile for all position of reinforcement and for both single and double layer. Optimum benefit of reinforcement was marked only if position of reinforcement of geo-textile layer is at M/3 and M/2 for both woven and non-woven geo-textile.

Increment ratio of double layer of reinforcement for both woven and non-woven was greater than of respective single layer. Performance of M5P predicts the CBR value for woven was better than ANN. Performance of ANN to predict the CBR value for non-woven was better thanM5P.

S. Ramjiram Thakur et. al. (2021) In the laboratory, they performed California bearing ratio (CBR) tests and came to the following conclusions- The addition of nonwoven geotextile materials to soils improves CBR and, as a result, soil strength. In many earthen structures, geotextile-reinforced soils will perform unreinforced soils, increasing load-carrying capacity.

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Conclusions:

Different articles and journals reviewed above tell us about the different properties and uses of geo-textiles when used in different fields and areas of civil work. It is concluded that the geo-textile used in all the research work or projects has an important impact on the enhancement of soil properties.

Shear strength, permeability, dry density, and CBR were determined before and after the geotextile was installed. Shear strength, dry density, and CBR enhanced by the addition of geotextiles, whereas permeability and penetration (check for settlement) decreased, indicating a significant improvement in engineering behaviour. As a result, geo-textiles serve a critical role in improving soil qualities by lowering compressibility and boosting strength. Because the future of geotextiles is very dynamic and will be motivated by different aspects such as cost, performance, and resource availability, there is a lot of need for more research in this area. Today, there are various competing philosophies in the field of geotextile use. On the one hand, there is an increasing demand for environmentally acceptable geotextiles, and on the other hand, there is a continuing need to make use of natural resources. The following is a list of potential research topics for future work.

The current study could be expanded to include other types of geotextiles and soils. More advanced technology, precise application procedures, and maintenance can be used in investigations including soft soil reinforcement. Field tests can be conducted to obtain more useful results. Degradation aspects and their impacts are frequently addressed in studies.

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