Journal of Current Research in Engineering and Science
Bi-Annual Online Journal (ISSN : 2581 - 611X)

Volume 6 –Issue 2, August 2023
Paper:87

Utilization of Non-Woven Geotextile Sheets in Soil Stabilization: A Review

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***Abstract*- The process of enhancing the subgrade soil's load bearing capability and engineering qualities to support structures and pavements is known as soil stabilization. India's current situation calls for the development of the most transit facilities available in the shortest amount of time possible. Due to its superior construction quality, ease of use, and time-saving feature, the use of geosynthetic materials as a ground improvement approach has won universal acceptance. Geosynthetics are materials that people have created that are used to reinforce soil in order to increase the soil's bearing capacity and permeability while lowering soil settling. In roadway projects without additional layers, such as cement concrete, asphalt concrete, or in a subgrade layer that impacts the bearing capacity of unbounded levels, geosynthetics application is crucial. The shear strength and deformation resistance of reinforced soils were greatly improved by the influence of varied numbers and positions of geotextiles with varying confining pressures. California bearing ratio (CBR) tests were performed in the lab to assess the load-penetration behavior of reinforced granular soils using geotextile. Different gradings of granular soil sample are chosen, and they are evaluated without reinforcement. Then, by inserting geotextile at a certain depth within the sample height in one and two layers, the impacts of geotextiles on the improvement in bearing capacity of reinforced granular soils are investigated. Thus, the geotextile performance grading can be analyzed.**

Keywords—Stabilization, geosynthetic materials, ground improvement technique, geotextile, pavement, reinforced soils.

1. Introduction

Soil is considered as one of the crucial basic materials for construction. The soil beneath will be significant when it comes to building a new structure and finally starting the construction phase. The base soil acts as cornerstone for any kind of construction project. Since soil is in direct contact with the building, it acts as a form of load-bearing system and disperses forces. Soil should meet the required conditions which make it suitable for building a strong and solid foundation. The foundation itself needs to be supported by solid ground capable of carrying all of the weight of the building. Since weak soil tends to contract and swell, it is essential to improve the soil properties which can be attained by the method of soil stabilization. Soil stabilisation is the biological, chemical, or physical alteration of the engineering properties of soil. It is a method for enhancing properties of soil like plasticity, compressibility, durability, mechanical strength and permeability. An increment in shear strength and bearing capacity of soil marks the stabilization of soil. After being stabilized, a solid layer is created which limits permeability and the bad impacts of freeze-thaw cycles. The original state of the soil can be improved through soil stabilization, reducing the cost of labour-intensive remove-and-replace operations. Chemical and biological treatments are used more often to regulate engineering qualities of soil in order to provide foundation for buildings, roadways, airfields or construction pads.

2. Soil stabilisation methods

The soil used for structural applications needs to meet specified requirements to have the necessary resistance to tensile stresses and strain spectra. Unbound elements can be stabilized with cementitious materials via soil stabilization. There are two approaches to implement the method i.e., in situ stabilization and ex situ stabilization. The choice for usage depends on whatever aspects of the soil need to be changed. Some stabilization techniques are listed below

2.1 MECHANICAL STABILISATION

This method of stabilization improves soil properties by altering the gradation of the soil. In this method, mechanical energy is applied to the soil in the form of vibrational techniques, rammers, rollers and occasionally blasting in order to densify and compact the soil. The natural characteristics of the soil material contribute to the soil stability in this approach. To create a compound that is superior to any of its constituent parts, two or more different kinds of soil are combined. A material that satisfies the necessary specifications can be created by mixing soils of two or more gradations.

2.2. STABILIZATION USING DIFFERENT ADMIXTURES

2.2.1Lime Stabilization: Lime stabilization is a method for enhancing soil wherein lime is introduced to the soil to enhance its qualities. Hydrated high calcium lime, calcite quick lime, monohydrated dolomite lime and dolomite lime are types of lime that are applied to the soil. Most stabilizers contain between 5% and 10% of lime. The term "lime modification" indicates strengthening impact caused by capacity for exchange of 3 cations. In soil modification, the natural clay particles flocculate into overlapping metalline formations. Clayey soil grows drier and becomes less sensitive to changes in water content The method of lime stabilization is mostly utilized in geotechnical applications. However, the process of stabilizing lime may be hampered by the presence of organic compounds. Sulphate, on reaction with lime, swells, which could affect the soil strength.

2.2.2. Cement Stabilization: When cement particles hydrate and lead to the formation of crystals that can join with one another to produce higher compressive strength, which is what is meant by cement stabilization. Most of the material particles must be covered by cement particles for an effective bond to form. A highly compacted mixture of soil, water and cement is known as soil-cement. As the cement hydrates, soil-cement transforms into a durable and hard substance. While the process of compaction is ongoing, cement stabilization is carried out. The amount of vacancy in the soil decreases as cement fills spaces between the soil particles. Following this, cement interacts with water and becomes hard when water is applied to the soil. Soil now weighs more per unit of weight. Clayey soils benefit from cement because it increases their workability and plasticity index while lowering their liquid limit. The main factor in cement reaction, which can occur in any soil is its reaction with water. This may be the cause of widespread use of cement in soil stabilization. A complex set of unidentified chemical reactions take place throughout the intricate process of cement hydration. To reach the desired strength, this should be considered when designing the mix. The two primary cementitious components of OPC (ordinary Portland cement), calcium silicates, are in charge of building strength. Another Portland cement hydration product, calcium hydroxide (C3S and C2S) combines with pozzolanic elements found in stabilized soil to create more cementitious material.

2.2.3. Chemical Stabilization: This method entails altering the physico-synthetic properties within soil particles so that less water is required by the earth to correct the static imbalance. In mechanically 4 stabilized soil, calcium chloride is employed as a water-retentive addition which act as a flocculant promoting compaction. The rate of evaporation reduces, the surface tension increases, and the vapor pressure drops. The freezing point of water drops, which prevents or lessens frost heave. Calcium chloride is applied more often to make up for the chemical loss caused by leaching activity. The relative humidity of atmosphere needs to be higher than 35% for salt to work.

2.2.4. Fly ash Stabilization: Fly ash stabilization has lately gained prominence due to its ubiquitous availability. Compared to other ways, this one is less expensive and quicker. It has a been used for a long time for geotechnical and other engineering purposes. Since it is a by-product of coal-fired electric plants, it has low cementing qualities to lime. Most of the fly ashes are secondary binders, which on their own are unable to provide the required effect. However, it can react with chemical activators and create cementations compound, which helps in strengthening soft soil. However, the following limitations apply to soil fly ash stabilization: (a) Dewatering of soil is necessary since soil should contain less moisture for proper stabilization (b) When soil-fly ash compound is cured below zero and submerged in water, it is susceptible to slaking (c) The strength and durability over the long term can be decreased by Sulphur content, which can create expanding minerals in soil-fly ash mixtures.

2.2.5. Rice Husk ash Stabilization: Rice husk ash is a commonly available, minimally manufactured pozzolanic substance that can be utilized to stabilize soil. When rice husk is burned at a controlled temperature, ash is created, and between 18% and 25% of the weight of it is still ash. Bagasse, rice straw, and rice husk ash are all silica-rich materials that work well for pozzolana. Additionally, it is doubtful that it 5 would be as reactive as fly ash, which is broken down more finely. So, when employed as a stabilizing substance, rice husk ash would produce excellent outcomes.

2.2.6. Bituminous Stabilization: A controlled quantity of bituminous substance is extensively blended with soil or aggregate material to provide a stable base. This procedure is known as bituminous stabilization. The use of bitumen improves the capability of soil to hold more weight and makes soil impervious to any effects of water. The kind of bitumen to use depends on the soil type that needs stabilizing, construction technique, and the weather conditions. Tar should not be used in locations that frequently experience frost because of its high susceptibility to temperature. Bituminous materials like asphalts and tars are typically used to build pavements and stabilize soil. When bituminous

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materials are mixed with soil, the soil becomes more cohesive and absorbs water less slowly.

2.2.7. Thermal Stabilization: The soil qualities improve significantly as a result of change in temperature. The soil is either heated or cooled to achieve thermal stabilization. By heating, the water content in soil declines. The strength of the soil is raised while the interparticle repulsion is reduced. Clayey soils experience a slight decrease of strength during chilling due to increased repulsion between particles. When the temperature falls below the freezing point, however, the pore water solidifies and stabilizes the soil.

2.2.8. Electrical Stabilization: The procedure of electro-osmosis is used to electrically stabilize clayey soils. In a clayey soil, pore water moves to cathode when a direct current (DC) is applied. It happens because cations present in the water are drawn to the cathode. Due to the absence of water, strength of soil has increased drastically. A costly technique, electroosmosis is mostly used to dry soils which are cohesive

2.2.9. Stabilization by Fabrics and Geo-textile: Geotextiles are synthetic, extremely strong, porous textiles made of nylon, polyvinyl chloride, polyethylene, and other synthetic fibers. Geotextiles come in woven, nonwoven, and grid shape variations. It increases the stability of the structure when appropriately buried in the ground. It is utilized when building unpaved roads over softer soils. Previous studies have demonstrated that the addition of nonbiodegradable reinforcing materials can increase the strength of subgrades and base course materials. The use of these materials may lower building costs while enhancing the durability of future roadways.

2.2.10. Recycled and Waste Products: Improved chemical stabilization techniques are needed for waste products such as paper mill sludge, copper and zinc slag, broken old asphalt pavement, and rubber tyre chips. Given the requirement to recycle several hazardous products, it is necessary to develop a useful, inexpensive, and effective way of evaluating the risk of contamination produced by these materials through leachates and emissions. Environmental constraints frequently make it challenging to assess hazards; as a result, this issue must also be addressed.

3. EFFECT OF SOIL STABILIZATION

Stabilized soils provide a stable working surface for all other project elements. The pozzolanic reactions after stabilizing methods can change weak soils indicating that soils are substantially less permeable and less prone to leaching, which reduces the possibility of shrinkage as well as expansion and increases resistance to freeze-thaw cycles. Additionally, stabilized soils have also gone through certain changes. In other words, soil has changed physically, which reduces flexibility and simplifies compaction. By an easier compaction, maximum dry density can be achieved easily. The important geotechnical parameter called the plasticity index considers the effect of water content of soil. The soils become more workable when the soil plasticity decreases.
Overall, any one or more of the following changes could be brought on by soil stabilisation:

- An increase in stability, a modification of physical qualities like swelling or density.
- Chemical property modification
- maintaining required strength by water proofing.

4. NEED FOR IMPROVING THE STRENGTH OF SOIL

Today, there is a greater demand for geotechnical buildings that are both economically and environmentally feasible. However, there are some restrictions on the building of such structures because of the high cost and issues with aggregate extraction. Shallow foundations cannot be used in those places if the soil is weak in shear, hence deep foundations are used instead. Because building a deep foundation is quite expensive, stabilising the unstable soil has been shown to be an effective option.
Road connections are determined to have advantages over other forms of communication in India because the country is predominately rural. However, delivering a safe and cost-effective road network to its users is made more difficult by several issues, including economy, time, and environmental limits. The existence of soft soil at ground level is one of the key issues that engineers working on highway development in India's plains and coastal regions must deal with. Due to its depth, these strata cannot be removed by excavation. Roads had to be built over them as a result. If there is inadequate or no drainage, this problem may become even worse. Most studies on the failure of these soft-soil roads points out to the presence of fine-grained dirt that gets mixed up with the aggregate base materials, weakening the aggregate by interfering with stone-to-stone contact. The lateral displacement of the subgrade and the foundation materials under load is linked to the poor performance of the subgrade. Clay has the largest capacity to hold water because clay particles are the smallest soil particles. However, this water tends to remain in the crevices between the clay granules and is difficult for plants to get which can lead to water logging in the places having this type of soil. A significant effect of the classic water logging issue is the disruption of traffic flow. Due to waterlogging caused by the capillary migration of water from the high-water table, the soil directly beneath the pavement gradually loses its bearing value and becomes progressively moist. High volume traffic pavements scatter the load on the subgrade and transfer it to the base course layer as a result of the waterlogged soil, which has an adverse effect on the strength of the traffic conveyance. If the subgrade soil is soft or weak, it will not bear enough traffic loads for long period of time which further leads to pavement deformation. Geotextile-reinforced soils perform better than unreinforced ones on unpaved roads and increase bearing capacity of soil. Surface penetration and deformation are decreased, and the stress distribution on the soil sample is

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improved, when geotextile reinforcement is introduced to soils. Finding alternative methods to increase soil strength and hence resolve traffic problems is crucial.

5. COMPOSITION OF GEOTEXTILES

In addition to considering the site's performance requirements for geotextiles, the selection of geotextile materials must be appropriate to the project's actual circumstances. Today, synthetic fibre is primarily the foundational component of geotextiles. The most often used material in geotextiles is polypropylene (PP), followed by polyethylene (PE), and polyethylene terephthalate (PET). A popular fibre for geotextiles because to its inexpensive cost, adequate tensile characteristics, and chemical inertness is polypropylene. A further benefit of this fibre is that it has a very low density, which results in a very low cost per volume. The biggest drawback of polypropylene is that it is not very sensitive to UV. Additionally, its performance is susceptible to degradation at high temperatures and has weak creep characteristics. PET is a significant synthetic fibre used in geotextiles. It has great creep resistance and excellent tensile characteristics. High temperatures can be employed with polyester fiber-based geotextiles. Polyester fiber's primary drawback is its ease of hydrolysis and degradation in soil with a pH value greater than 10. Although polyethylene fibre is typically used to create geomembranes, it is now only occasionally used as a geotextile's solution due to a scarcity of availability. In addition, polyamide is rarely utilised in geotextiles because of its low cost and subpar overall performance. Antioxidants, hindered amine light stabilisers, UV absorbers and stabilisers, long-term thermal stabilisers, processing modifiers, flame retardants, lubricants, and antibacterial agents are just a few examples of the additives commonly used to improve the performance of geotextiles.

6. FUNCTIONS OF GEOTEXTILES

The use of geotextiles in the construction industry is huge because of the remarkable functionalities. Geotextiles have excellent fluid transmission properties. They can capture a liquid or gas during fluid transmission and can move it along its own plane in the direction of an outlet. Geotextiles are used as a filter. This enables the liquid to flow normally through it to its own plane but prevents the passage of soil particles into it. A geotextile serves as a separator when it is positioned between fine and coarse particles. Here, the geotextile prevents the frequent action of loads from combining fine particles and coarse material, such as gravel and stones. By distributing the stresses and strains applied to a material, geotextiles serve to protect the material as well. The geotextile serves as a tension membrane when it is positioned between two materials at differing pressures. It tries to reinforce the structure while balancing the pressure differential between the two materials. Additionally, the geotextile functions as a tensile member when it gives soil tensile modulus and strength. This increase in strength is a result of the soil's cohesion, interlocking, and friction with the geotextile. Since the geotextile is a permeable material, it contributes significantly to drainage for most civil engineering constructions like dams, road pavements, embankments, etc., where water drainage is crucial. Different underdrain systems should be built for various constructions. Geotextiles are used in these constructions for drainage, which increases the effectiveness of the under-drainage system and makes construction simpler.

7.SOIL STABILIZATION USING NON-WOVEN GEOTEXTILES

Geotextiles are those synthetic fibre sheets that are permeable, such as polyester, polypropylene, nylon, etc. Geotextile permeability is like that of fine to coarse sand. They are highly sturdy and long-lasting. Even an unfriendly soil environment does not have an impact on them. The continuous or stable fibers used to create non-woven geotextiles are linked at the fibre cross-overs either through mechanical bonding (needle punching), thermal, or chemical bonding. They have been widely employed to create impermeable barriers as well as for filtration, separation, and drainage purposes.

In order to strengthen the soil and create a reinforced composite soil, geotextiles are inserted into the interior of the soil. Through the tensional membrane and tensile member serving as reinforcement, a geotextile layer offers reinforcement. Better load distribution is ensured, particularly for materials with high modulus and heavy weight. Inducing tension in the fabric under dynamic stresses serves as reinforcement because of membrane action. Geotextiles maintain low levels of stress and are mobilized by vertical loads. When a fabric is under strain, the stress is dispersed over a larger surface area, which lessens its intensity. The soil beneath geotextiles is stabilized when they are placed there. It enhances the soil's shear strength, which raises the soil's bearing capacity and allows the soil to support heavier loads. The drainage activity of the geotextile, which the water seeping through the ballast runs through, further strengthens this impact by removing it off the road bed. When geotextiles are used to strengthen soil, their main function is to give the soil tensile strength, which would otherwise make the soil relatively strong in compression and weak in tension. It is crucial that the chosen geotextile can provide this tensile strength at a strain level that is suitable for the soil structure's functionality. For geotextile soil reinforcement, a high tensile stiffness is typically also needed because substantial deformations are typically unacceptable in such constructions.

Geotextiles offer various benefits over other soil-reinforcing materials. They are resistant to all naturally occurring chemical attacks in soil, especially from alkalis and acids. They have been proven to be stable from -60℃ to 100℃. However, at really high temperatures, the strength is known to decrease. They can withstand prolonged exposure to sunshine or moisture, are resistant to organic pests like bacteria and fungi, and are not enticing to rodents and termites. The synthetic fibre mats are renowned for supporting and promoting the growth of grass-like

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vegetation. Additionally, the geotextiles include enough black carbon, which provides them with suitable protection while being stored outside before being used. It has been extensively utilized to reinforce railroads, paved and unpaved roads, walls, berms, and slopes, as well as soft soil foundations.

8. EXPERIMENTAL STUDIES

The CBR test can be carried out according to the recommended procedure described in IS-2720 (Part-16) in order to understand the impact of non-woven geotextiles on clay soil. The specimen can be compacted in three equal layers on OMC to get the necessary density. The quantity of dry soil and water necessary for filling the mould can be found out by conducting the Standard Proctor test on the soil. The geotextile can be cut into a circular disc that will be slightly smaller in diameter than the CBR mould and it can be placed in between the soil layers at a height of H/6, H/2 and 5H/6 from top of the sample, where H is the height of the sample in CBR mould. It is crucial to consider the impact of moisture variation. As a result, the soaked condition is suitable for the CBR test. Under controlled conditions (at 27°C), the soil sample with a surcharge of 4.6 kg will be immersed in water for 96 hours and the CBR testing will be carried out after the 96-h soaking time. The CBR values that will be obtained in this experimental study helps to analyse the effect of geotextile on the soil wherein the results will be affected by the position of the geotextile sheets in between the soil layers. Furthermore, thickness of the geotextile also has an effect in the strength it imparts to the soil layer. The choice of CBR test apparatus is of prime importance as the testing platform brings some inherent problems into the experimental study. Small size of the CBR test apparatus limits the size of the geotextile sheet. End effect in such a small sample size can be more pronounced than that of the other large-scale model tests. Despite these limitation, a large experience base has been developed using the CBR test, and some satisfactory design methods are in use based on the test results.

9. CONCLUSION

The problem of having to lay pavement over weak subgrade soils can lead to its failure in the course of its life which in turn leads to the unnecessary wastage of material and capital. Since roads are of greatest importance in the society, the designing and construction of them must be made such that they are durable and will not be turned into a threat in the future. Therefore, incorporating modern techniques such as a geotextile sheet will be advantageous. Several studies shows that the inclusion of non-woven geotextile with the soil increases the load carrying capacity and decreases the immediate settlement of the soil. Thus, non-woven geotextile can be used as they can increase the strength of the subgrade soil thereby providing a better paved road for the society.

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