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Stabilization of soil using geotextile

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Abstract
Engineering projects frequently use soil stabilization to boost soil strength and save building costs. Due to their many advantages over traditional stabilization methods, geotextiles, a type of geosynthetic material, have gained prominence during the past ten years. Geotextiles are permeable, flat sheets constructed of polypropylene or polyester resin with yarns that have been knitted, needle-punched, woven, thermally or chemically bonded, or combined all of these techniques. They can be created using materials that are readily available in the area, are inexpensive, and are easy to install. They are a great solution for big-scale construction projects like paving because they don't need highly skilled workers and their quality can be readily managed.
Through a partial interaction between the soil and the geotextile material, the process of improving the soil with geotextile increases its stiffness and load-carrying ability. This enables the pavement system to have a lower overall thickness while extending its lifespan and lowering maintenance expenses. An important benefit of using geotextiles for soil stabilization is that it eliminates the requirement for expensive earth resources to be extracted from rented pits. Instead, the first earth elements found on the construction site can be used to pave roads, cutting down on construction expenses and the project's impact on the environment. Geotextiles are also good at keeping base layers and subgrade particles from blending together. When there isn't a geotextile at the subgrade/base course interface, the subgrade contaminates the aggregate. Particles, which reduces the overall durability of the pavement system. When subjected to dynamic loadings, geotextile-reinforced soils outperform conventional soil, making them suitable for use in pavements for roads and airports.
Using geotextiles for soil stabilization is a cost-effective and sustainable approach to pavement construction. It offers several benefits over traditional soil stabilization methods and can aid in reducing construction costs, increasing service life, and minimizing the environmental impact of construction projects.

Keywords: Geotechnical test, geotextile, woven fibre, non-woven fibres, stabilization of soil

Introduction
Soil stabilization is a crucial aspect of civil engineering projects to ensure the longevity and safety of infrastructure. Geotextiles have emerged as a popular and effective solution for soil stabilization in recent years. In this journal entry, we will explore the concept of soil stabilization using geotextiles, their benefits, and their effectiveness in ensuring the stability of the soil.

What are Geotextiles?
Geotextiles are flat, permeable sheets constructed of polyester or polypropylene resin with yarns that have been knitted, needle-punched, woven, thermally or chemically bonded, or bonded with a thermal agent. They belong to a class of geosynthetic materials that are frequently employed in civil engineering projects to stabilize the soil. In comparison to conventional stabilization methods, geotextiles offer a variety of benefits, including simplicity of installation, lower cost, and enhanced performance.

Benefits of Geotextiles for Soil Stabilization
Geotextiles have many advantages to stabilizing soil. First, because geotextiles may be laid with local resources, less expensive earth materials need to be carried to the construction site. This lowers expenses while simultaneously lowering the project's negative environmental impact. Second, the intermixing of base layers and subgrade particles, which can reduce the overall strength of the pavement system, can be effectively avoided by using geotextiles. Third, it has been shown that geotextiles can make the soil more rigid and capable of holding more weight, reducing the pavement system's overall thickness while extending its lifespan and lowering maintenance costs.

Effectiveness of Geotextiles for Soil Stabilization

Several research have been done to determine how effective geotextiles are at stabilizing soil. According to these investigations, geotextiles are quite successful at enhancing the soil's strength and stability. It has been demonstrated that geotextile-reinforced soils perform better than conventional soils under dynamic loadings, making them perfect for usage in pavements for roads and airports.

The process of enhancing the subgrade soil's load-bearing capacity and engineering qualities to support structures and pavements is known as soil stabilization. This study investigated the use of geotextile as reinforcement to stabilize two soil samples (lateritic and clay). Particle size analysis, the Atterberg Limit test, moisture content, specific gravity, the compaction test, and the California Bearing Ratio test are all performed as part of geotechnical testing.

Woven-Fabric Geotextile

Commonly found geotextiles are of the woven type and are manufactured by adopting techniques similar to weaving usual clothing textiles. This type has the characteristic appearance of two sets of parallel threads or yarns. The yarn numbing along the length is called the warp and the one perpendicular is called the weft.

Fig 1: Woven Geotextile

Non-Woven Geotextile

Non-woven geotextiles are manufactured from either continuous filament yarn or short staple fiber. The bonding of fibers is done using thermal, chemical or mechanical techniques or a combination of techniques.

Fig 2: Non-Woven Geotextile

Table 1: Difference between the woven and non-woven geotextiles

Geotextiles	
Woven	**Non-Woven**
Separation	Separation
Reinforcement	Filtration
High Load Capacity	Drainage
Plastic Like	Felt-Like
Referred To by Tensile Strength	Referred To by Weight
Impermeable	Permeable

Literature Review

Geotextiles are frequently used to stabilize soil and boost the effectiveness of paving systems. They ensure that the overall strength of the pavement system is not compromised and protect base layers from contamination by subgrade particles. Geotextile-reinforced soils outperform conventional soil under dynamic loading situations, and they are robust, non-biodegradable, and extend the pavement's overall service life, according to D.A. Ogundare (2018) (1).

According to A.K. Choudhary, K.S. Gill, and J.N. Jha (2011) (2), adding more layers of reinforcement to geotextiles lowers their expansion ratio and raises their California Bearing Ratio (CBR) value. They discovered that geogrid is more effective in strengthening soils than jute geotextile.

According to Kaku *et al*. (2007) (3), geotextiles are also helpful in landscaping to control weeds and preserve soil conditions for plant growth.

In 1987, R. M. Koerner of Drexel University in Philadelphia (4) distinguished between areal fill for stabilization and linear embankments for containment dikes or barriers. Both instances offer a wide range of potential applications and are currently the subject of intensive activity.

According to Jon A. Epps, Ph.D. and Wayne A. Dunlap, Ph.D. (1970) (5), soil compaction is a practical and affordable strategy for stabilization. Additionally, chemically stabilized soils need to be properly compacted.

According to Ankit Singh Negi *et al*. (6), lime works well as a soil stabilizer for highly dynamic soils that frequently expand and contract. Using lime strengthens the soil's ability to carry loads, lessens the soil's tendency to shrink under wet conditions, lowers the plasticity index, raises the CBR value, and improves compression resistance over time. Within a few hours, the stabilization process gets started.

Anil Pandey *et al*.'s (7) investigation into cement-based soil stabilization. The researchers came to the conclusion that soil cement is a desirable base or sub-base material because it offers strength and durability. It is also a great substitute material for affordable construction.

In a study on bituminous soil stabilization, Sabbani Venkatesh (8) discovered that cationic bituminous emulsion is useful for enhancing subgrade soil strength.

Rathan Raj R *et al*. (9), who studied the impacts of solid waste such as rice husk ash on the variance of different index values, shear strength, CBR value, and compaction characteristics of clay soil, examined the stabilization of soil with rice husk ash. The outcomes demonstrated that clay soil can be strengthened and have its qualities enhanced by rice husk ash.

It is significant to note that these conclusions about geotextiles and soil stabilization have been independently investigated and reported; therefore, care should be made to ensure that the appropriate methods and materials are employed for each individual application.

Objectives

Sub-grade, sub-base, and course strength can be altered using the technique of soil stabilization to boost their bearing capacity by utilizing inexpensive, locally accessible soils and building materials, this strategy can also assist reduce the cost of building roads.

The process of stabilizing soil helps to improve some unfavorable characteristics of soils including excessive swelling or shrinking, high flexibility, and difficulties compacting. It reduces compressibility and minimizes settlements by facilitating compaction and boosting load-bearing capacity.

In addition, soil stabilization can enhance the soil's permeability properties, enabling better drainage and lowering the chance of water-related damage. before beginning any project, it is crucial to do a careful analysis of the soil's features and attributes.

Deciding on a soil stabilization strategy may include carrying out laboratory experiments to ascertain the strength and compressibility of the soil as well as field testing to evaluate the behavior of the soil under load.

Research -methodology

The mode of operation of a geotextile in any application is defined by six discrete functions:

- Filtration
- Drainage
- Reinforcement
- Cushion
- Waterproofing
- Separation

The flexible material geotextile is frequently used in the construction of roads for a number of purposes, including separation, filtration, strengthening, and sealing. One of its main uses is to function as a separator and stop the mixing of two adjacent soils. For instance, the drainage and strength characteristics of the aggregate material can be maintained by sandwiching geotextile between fine sub-grade soil and aggregates of the base course.

By permitting liquid flow while preventing soil loss across its plane, geotextile also contributes significantly to filtration. This is made feasible by the geotextile's porosity and permeability characteristics, which provide sufficient liquid movement without jeopardizing the stability of the soil system.

Another benefit of geotextile is its capacity to strengthen the soil, much like steel does system.

Finally, geotextile can also be employed as a sealant. To form a waterproofing membrane, a non-woven geotextile layer can be impregnated and placed between the old and new asphalt layers. This contributes to decreasing the vertical flow of water into the pavement structure, hence increasing pavement longevity and lowering maintenance costs.

Table 2: Type of geotextiles

Function	Type of geotextiles recommended
Drainage	Non-woven (light or medium wt.)
Separation	Non-woven (Heavy wt.) Woven
Reinforcement	Non-Woven (Heavy wt.) Woven
Cushion	Non-Woven (Light wt.) Woven
Filter	Non-Woven Woven

Test

Moisture content

The natural water content also called the natural moisture content is the ratio of the weight of water to the weight of the solids in a given mass of soil. This ratio is usually expressed as a percentage. To sight a few, natural moisture content is used in determining the bearing capacity and settlement. The natural moisture content will give an idea of the state of the soil in the field.

W = [(W2-W3)/(W3-W1)] * 100

Specific gravity

Table 3: Test Results

Particulars	Sample A	Sample B
Liquid Limit (%)	36.10	43.60
Plastic Limit (%)	19.40	29.30
Plasticity Index (%)	15.10	14.30
Moisture Content (%)	18.10	19.20
Optimum Moisture Content (O.M.C) (%)	14.50	12.00
Max. Dry Density(g\cm^3)	1.29	1.35
Specific Gravity	2.72	2.60

Specific gravity (G_S) is a property of the mineral or rock material forming soil grains.

It is defined as

$$G_S = \frac{\text{Mass of soil}}{\text{Mass of water displaced by soil}} = \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$$

[The range of G_S for common soils is 2.64 to 2.72]

Compaction

The dry unit weight (γ_d) is calculated as follows:

$$\gamma_d = \frac{W - W_m}{(1 + w) * v}$$

Where:

W = the weight of the mold and the soil mass (kg)

Wm = the weight of the mold (kg)

w = the water content of the soil (%)

V = the volume of the mold (m3, typically 0.033m3)

The derived dry unit weight along with the corresponding water contents are plotted in a diagram along with the zero-voids curve, a line showing the dry unit weight correlation with the water content assuming that the soil is 100% saturated. No matter how much energy is provided to the sample, it is impossible to compact it beyond this curve. The zero-void curve is calculated as follows:

$$\gamma_d = \frac{G_s * \gamma_w}{1 + W * G_s}$$

Where
GS = the specific gravity of soil particles (typically, GS~2.70)
γ_w = the saturated unit weight of the soil (KN/m3)
Typical curves derived from the Standard and Modified Proctor tests, as well as the zero air voids curve.

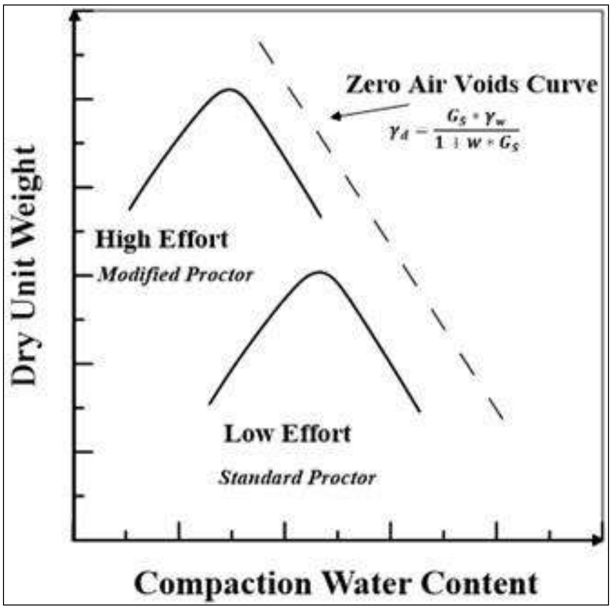


Fig 3: Dry unit wt. vs Water content

Atterberg limits
Testing of Atterberg limits is performed only on the soil fraction passing through a No. 40 sieve, according to ASTM D4318-00 (ASTM, 2003). Therefore, mixtures of cohesive clayey soil and fine rubber particles (< 0.425 mm size) have been studied and results showed that as the percentage of tire rubber increased, the clay content decreased and consequently Atterberg limits also decreased. In particular, the liquid limit stayed unchanged until levels of waste tire reached 30%, and then it started to decrease; the plastic limit stayed about the same up to 10% waste tire inclusion levels, started to decrease at levels of 20% and then stayed the same. The plasticity index was found to stay the same for rubber chips up to 10% inclusion levels, while according to N. Oikonomou and S. Mavridou this was found to slightly decrease as the percentage of rubber increased to 10%.

CBR Test
The California Bearing Ratio or CBR test is performed in construction materials laboratories to evaluate the strength of soil subgrades and base course materials. Those who design and engineer highways, airport runways and taxiways, parking lots, and other pavements rely on CBR test values when selecting pavement and base thicknesses.

C.B.R. = (PT/PS) X 100

Where, PT = Corrected test load corresponding to the chosen penetration from the load penetration curve. PS = Standard load for the same penetration.

Table 4: CBR Experiment

Sample	Without Non-Woven		CBR (%)	With Non-Woven		CBR (%)
	2.5 mm	5 mm		2.5 mm	5 mm	
A	3.5	3.9	3.8	14.1	14.9	15.0
B	5.8	6.6	6.9	20.2	17.2	21.0

Fig 4: Soil Sample

Tensile strength

- **Wide width tensile test**

Samples of a particular size must be prepared in order to test geotextile specimens. Samples that are 200mm wide and 100mm long in both the warp and weft directions are needed for this purpose. For evaluating these samples, the machine strain rate should be 103% per minute. It is crucial to highlight that the choice of wide-width samples was made since geotextiles, particularly nonwoven ones, frequently acquire high Poisson's ratio values when put through testing on a narrow strip. Therefore, it is essential to use larger samples during the testing process in order to achieve reliable and representative results. The specimens should be mounted centrally once they have been processed to guarantee consistent and accurate testing. By adhering to these recommendations, It is feasible to gather trustworthy and pertinent information about the toughness and longevity of geotextiles, which can then be used to create and put into practise efficient pavement separation systems.

Tensile strength measure as Tgeotextile = Fb/ W (kN/m)
Fb = Observed breaking force (kN), and
W = Specimen width (m)

- **Narrow strip tensile strength**

Narrow strip sample size 75 mm x 25 or 50 mm, strain rate 300 mm/min, tensile strength appears to be less than wide width tensile strength, not recommended as design value

Grab tensile strength
To ascertain the efficacy of geotextiles, particularly in separator applications in pavement, a construction survivability test is required. With an initial clearance of 75 mm and a loading rate of 300mm/min, the specimen is tested using 25 mm narrow width grips. Nonwoven

geotextiles often have a bigger impact than woven ones in the test because it depends on the interaction of the filaments in the geotextile. The geotextile's tensile strength is measured in KN. However, because the sample is only partially clamped, the stress does not spread across the sample's entire width.

The grab tensile strength is needed to design geotextiles for separation. The two lower stones are stretched laterally when pressure is applied to the higher stone, which releases tension in the geotextile. Similar to the grab tensile strength test, this tension exists. These tests can be used to decide whether a geotextile's strength and durability are suitable for situations involving pavement separation. To maintain the integrity of the pavement system, it is crucial to make sure that the geotextiles can sustain the anticipated loads and stresses.

D= Diameter of stone

1_i= Initial length = D/2 + D/2+D/2

l_f= final length = D+2 (D/2)

Without any stone breakage or slippage, maximum strain in geotextile can be expressed as,

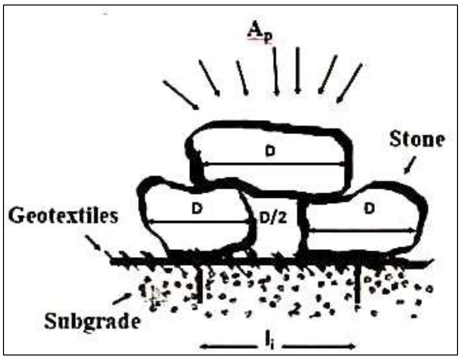
$$\varepsilon = \frac{l_f - l_i}{l_i} X100 = \frac{[D + 2\frac{D}{2}] - [\frac{D}{2} + \frac{D}{2} + \frac{D}{2}]}{\frac{3D}{2}} = \frac{1}{3} = 33\%$$

$$T_{reqd} = A_P \, (Dv)^2 \, \varepsilon$$

T_{reqd} = required grab tensile strength reqd

A_p = Applied pressure

D= Maximum void diameter = $0.33D_a$



D_a= Average stone diameter

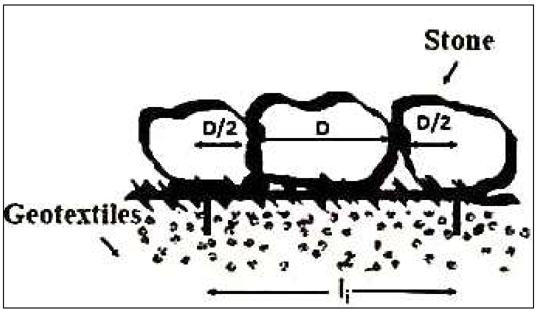


Table 5: MPU & GTP results

Particular	Non-Woven Geotextile
Mass Per unit (g\m^2)	205
Grab Tensile Strength	705

Conclusion

There are various crucial processes in the manufacturing process that must be followed to guarantee that the finished products comply with the appropriate standards and laws. These actions entail locating the product, choosing the right materials for it in accordance with the design guidelines and legal requirements, and monitoring the product's quality as it is being produced.

Additionally, it is crucial to guarantee that the items fit the requirements for the use for which they are designed. To ensure that the items are flawless and satisfy the criteria, testing and inspection are required. In order to make sure that a product will work effectively and meet the requirements for a certain use, it is also critical to evaluate its appropriateness for that purpose. This evaluation entails evaluating the product's manufacturing process, materials, and design to make sure it is suitable for the intended application. Manufacturers can make sure that their products satisfy the essential quality requirements and are appropriate for their intended usage by taking these actions and doing thorough assessments. Design engineers must have a good understanding of the necessary specifications in order to choose the best geotextile material for a project. Without this knowledge, it may be difficult to choose the ideal geotextile for the project's unique requirements.

Conducting testing on the material through an impartial laboratory is one technique to confirm that the chosen geotextile material complies with the required criteria. The data sheets that manufacturers often supply. These sheets may not provide the degree of detail required to ascertain whether a specific geotextile material is suitable for a given project, but they do include minimum average roll values (MARV) for quality control.

It is crucial to take samples of the material from the project site and send them to a lab for testing in order to reduce the environmental impact of utilising geotextiles in building projects. The strength, permeability, and durability of the geotextile may all be learned through this testing, which can assist confirm that the material is suitable for the demands of the particular project. Design engineers can choose the right materials for a project by thoroughly evaluating and analysing geotextile materials. This helps to ensure that the project is finished successfully while minimising its environmental impact.

Table 6: Advantages with or without geotextiles in road and highways

GEOTEXTILES IN ROAD AND HIGHWAYS	WITHOUT GEOTEXTILES	WITH GEOTEXTILES
REDUCED POTHOLES	✓	✓
CAN CONSTRUCT ON SOFT SOIL	✗	✓
QUICK INSTALLATION	✗	✓
BETTER LOAD-BEARING CAPACITY	✗	✓
COST EFFECTIVE	✗	✓
INCREASED LIFESPAN	✗	✓

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