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# SUSTAINABLE SOIL STABILIZATION TECHNIQUES IN GEOTECHNICAL ENGINEERING: A CRITICAL REVIEW

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**Abstract:** Soil plays a key part in civil engineering, but in general, natural sources of soil very often do not possess such essential features as strength, rigidity, and stability. Soil stabilization can be defined as a set of methods applied to improve the stability and quality of soils, either through soil compaction or concrete addition. The current paper will be focused on different options of soil stabilization, such as lime stabilization, cement stabilization, fly ash utilization, and many others. The advantages and disadvantages of different methods will be discussed as well.. Although numerous methods have been invented, one method can hardly be effective in case of any type of soil. Effectiveness of soil stabilization methods depends on the properties of the soil in question and moisture content, additives used, how well they combined with soil, etc.

## 1. INTRODUCTION

Soil is the base and the support for civil engineering structures. Its qualities change depending on the size of the particles what minerals are in it how water it has, how dense it is and its history. Weak or bad soils might have strength, too much sinking, a lot of compression, bad drainage, erosion or shrinking and swelling. These problems can affect roads the stability of hills and the ability of foundations to work.

Soil stabilization is the process of making some soil qualities better so that the material's good enough for a project. The goal might be to make the strength and stiffness make the soil less sticky or less likely to expand make it easier to work with control how much water goes through it or make it better at dealing with wet and dry conditions. Methods like using lime and cement are already in use. Researchers are looking more at using waste materials and biology to make less harm to the environment.

The best method depends on the kind of soil what is needed what equipment is available what materials can be used, the cost and the environment. Stabilization should be seen as a planned engineering process of just adding a certain amount of an additive.

## 2. REVIEW METHODOLOGY

This report takes a look at some of the published studies and technical publications relating to ground improvement. Such studies have been sourced on the grounds of soil waterproofing, the use of lime and cement, earth-friendly materials, and biological ground improvement within the domain of geotechnical engineering. A review distinguishes between sources which have been peer-reviewed. The working procedure, advantages, and limitations of various methods are covered by this review.
As for the discussions, they have been structured according to the treatment method and its engineering application. The differences in soil properties and experimental conditions of various studies make the comparison of their results difficult.

## 3. OBJECTIVES OF SOIL STABILIZATION

Objectives of Soil Stabilization
* To increase the strength and stiffness of soil so it can safely carry loads.
* To reduce soil plasticity, compressibility, swelling, and shrinkage.
* To make soil easier to handle, compact, and use during construction.
* To improve the soil’s resistance to water damage and erosion.
* To use suitable locally available and recycled materials while reducing environmental impacts.

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## 4. MAJOR SOIL STABILIZATION TECHNIQUES

### 4.1 Mechanical Stabilization

Mechanical soil stabilization is a technique used to improve soil properties without the use of chemicals. By rearranging the particles of soil, changing its composition or compacting it, mechanical soil stabilization is performed. In mechanical soil stabilization applications such methods as removing soft soil, soil mixing, compaction and application of geosynthetics have been used for installation. It is important to ensure proper water supply and compaction in order to reduce the space in the soil.

The main positive sides of mechanical soil stabilization are that it is inexpensive, easy to execute and utilizes conventional methods. Nevertheless, the downside of mechanical soil stabilization is that it works less efficiently with highly plastic clay, expansive soil and other problematic soils.

### 4.2 Lime Stabilization

Lime is used a lot with soils that have particles, especially clay. At first it can make the soil less sticky and easier to work with. Over time it can form things that make the soil stronger. Lime can help make some soils less likely to grow but how well it works depends on what kind of clay's there the chemistry of the soil how much lime is used how well it is mixed and how long it is left to set.

Lime isn’t good for all soils. Soils that have a lot of material or that have the wrong chemistry or that are not mixed or set right may not improve much. The amount of lime should be chosen using lab tests like the Atterberg limits, pressing and strength tests, not a general idea of how much to use.

### 4.3 Cement Stabilization

Cement can hold the soil particles together. Make the soil stronger and stiffer. It is often used with gravelly soils and soils that're not too sticky for the base of roads the layer under the road and parts of the road that use cement. The work usually involves spreading the cement mixing it evenly with the soil adjusting the water pressing it down and letting it set.

Cement stabilization can give results early on but making cement has a big effect on the environment. Soils that are very sticky have a lot of material are not mixed well not set right or exposed to tough conditions might not work well. The mix design should look at strength how long it lasts, how much it shrinks and what is needed for building.

### 4.4 Industrial By-products and Alternative Binders

Materials like fly ash, ground granulated blast-furnace slag (GGBS) cement kiln dust and rice husk ash have been studied as things to add to soil or as parts of mixes. How they work depends on what they're made of how fine they are, how much calcium they have how alkaline they are and if there are things added to make them work better. Good materials can reduce the need for binders and help get rid of waste.

These materials should not be used in the way. Some can't bind by themselves. Need lime, cement or something else. Others can be very different from one place to another. Checking the environment is important to see if bad stuff could come out and to make sure that using them is right for the place.

### 4.5 Bio-mediated and Biopolymer Methods

The use of bio-mediated techniques involves a living organism or products of a living organism to help enhance soil quality. In particular, MICP (microbial-induced $CaCO_3$ precipitation) is an example of a bio-mediated technique used to consolidate soil particles. Similarly, EICP (enzyme-induced $CaCO_3$ precipitation), which employs enzymes for the same effect, is another bio-mediated method used in improving soil particles. Microbial polysaccharides can also play an important role in the quality of soils depending on the type of soil and polysaccharide used. Although the above-mentioned methods appear to be very promising in controlling soil erosion and stabilization, the practical application of bio-mediated technologies still encounters a number of challenges, such as the cost of application, sensitivity to environmental conditions, resistance to wetting and drying cycles, by-product generation, and difficulties of scaling laboratory techniques. Therefore, each technique must be carefully tested before it can be effectively applied in a real-life situation.

## 5. ENGINEERING APPLICATIONS

The base of roads and layers of the road, hills, work sites, dams or some places that are subjected to erosion and some techniques to improve the ground rely on stabilized soils. Lime and cement is often chosen in case strength or behaviour

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of soil is needed. Improvement of the soil is the main objective of the earth moving process. The advantage of utilizing by-products and bioengineering process is possible only if they are environmentally friendly and produced in a proper way.

The correct choice of treatment depends on what the project requires. For instance, the road base may require CBR or the degree of the strength. Expanding soils used for the construction of foundations may need controlling their dimension. The treatment of slopes not only requires strengthening the soil, but also needs drainage system and protection from erosion.

## 6. RECOMMENDED DESIGN AND QUALITY-CONTROL WORKFLOW

1) Recommended Procedure for Design and Quality Control
2) Perform geological evaluation and sampling and carry out soil classification, particle size analysis, Atterberg test, measurement of natural water content, and other chemical tests necessary for the project.
3) Define performance specifications such as CBR, unconfined compressive strength, swelling prevention, permeability, region, etc.
4) Assess the possible stabilization option in terms of soil characterization, the availability of products, costs, construction feasibility, environment issues, etc.
5) Prepare test mixtures with different proportions of binding agents, and when applicable, use various additives in the mixtures.
6) Perform tests on the compacting characteristics and engineering properties of the prepared mixtures, and perform curing and durability tests when applicable.
Select the mixture that satisfies all desired engineering, social, and environment-related parameters.

## 7.GAPS

A big problem is that how well soil stabilization works depends a lot on the soil. Results from one kind of clay or sand can't be used for another. Many studies use ways to prepare the samples how much additive is used how long it is left to set and the rules for testing making it hard to compare. Sustainable additives can have chemistry and the proof from the real world isn't as much, as what is found in the lab.

Future work should focus on using test methods watching how things work over a long time in real outdoor conditions checking how long things last when they get wet and dry and when they are under pressure looking at the whole life of a product and how much it costs and testing how safe it is for the environment. Research should also look at how treatments work in real situations and create useful advice for choosing the right mix of mechanical, chemical and biological methods.

## 8.CONCLUSION

Making soil better is a method used to fix bad soil. Traditional ways like using machines, lime and cement are still used techniques for improving soil; however it is also possible to use waste materials from factories well as natural methods. Choosing the way is very important.

You should not just believe what is said about the method of making soil better. Instead you should look at factors like what the soil is like the results from tests in the lab and so on. The methods that are good for the environment and work well should also last over time.The author thanks the project guide, Deepika Firake for help and support in writing this review paper.

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