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Ground improvement techniques for structure stability

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Abstract
This paper provides a concise overview of ground improvement techniques essential for addressing soil challenges in construction. Focusing on both traditional and innovative methods, such as compaction, grouting, and soil bioengineering, the abstract highlights principles, applicability, and environmental considerations. Emphasizing recent advancements and sustainable practices, the paper underscores the importance of tailored solutions to mitigate settlement, liquefaction, and bearing capacity issues. This succinct exploration aims to equip engineers with the knowledge needed to navigate diverse soil conditions and make informed decisions, ensuring the success and longevity of construction projects.

Keywords: Compaction, grouting, liquefaction, settlement, bearing capacity

Introduction
The technique of modifying the existing site foundation soils to improve performance under design and/or operational loading conditions is known as "ground improvement. In order to make sites with poor subsurface conditions usable for new developments, ground improvement techniques are being adopted on an increasing basis. To put it briefly, ground modification is done to improve bearing capacity, decrease the size of settlements and the time it takes for them to form, delay seepage, speed up the rate at which drainage happens, improve slope stability, reduce the possibility for liquefaction, etc.
In this paper, some of the major recent and conventional technologies are discussed with their applications in the field and their advantages and disadvantages.

Objectives
- In order to make a site with poor subsurface conditions suitable for new projects, ground improvement techniques are being adopted more frequently.
- Ground improvement is executed to increase the bearing capacity, reduce the magnitude of settlements and the time.

Methodology
There are several methods for stabilizing soil. These techniques primarily rely on the type of strata and the improvement goal. Soil stabilization techniques can be broadly categorized as:
a) Soil improvement using additives.
b) Soil improvement using mechanical methods.
c) Soil improvement without using admixtures.
d) Soil improvement using thermal methods.
e) Soil improvement using Addition and Confinement Techniques.

Soil improvement using additives
Certain additives such as lime, bitumen, fly ash and cement etc. are added onto the soil at site to improve its characteristics. These may be classified as following:

Lime Stabilization: In a variety of circumstances, lime can be applied to soils to enhance their workability and capacity to support weight. Quicklime delays the reaction time with soil by about 1.25 times the time taken by slaked lime. When lime is used as a stabilizer, the long-term permanent strength, stability, and stiffness are improved, especially in fine-grained soils and occasionally in fine-grained fractions of granular soils, especially with regard to the action of water and frost [1].

For coarse-grained soils, 2-8% of lime may be needed, and for plastic soils, 5-8% of lime may be needed [2].

Cement Stabilization: One of the earliest binders used in soil stabilization techniques is cement. Cement and soil react to form a hard mixture known as soil-cement [1, 2]. This mixture is made of Portland cement, water, and ground soil. This is accomplished on site with specialized machinery. It is believed that the cement's chemical reactions with the siliceous soil during the hydration reaction are what cause the cementing action [1]. The characteristics of soil cement are influenced by a number of variables, including the type of admixtures used, compaction, curing, and mixing conditions. This method is used to stabilize weak soils at a deeper depth, such as soft soils and peaty soils, as well as to stabilize highways and embankment material at shallow depths [3, 4].

Fly Ash Stabilization: As a waste product from thermal power plants, fly ash is typically utilized in a range of processes [5]. The remaining fly ash is kept in lagoons as slurries, with about 15% being used in the production of cement and bricks [6]. Because fly ash is so abundant, even though it has less cementitious qualities than cement and lime, it has become a more and more well-liked alternative in recent years. Fly ash has the potential to be utilized in land reclamation and as a subgrade stabilizer [6, 7].

Jet Grouting: Grouting contractors use the term "jet grouting" to refer to a broad range of construction methods used for improving or modifying the ground. High-velocity injections of binders or high-pressure fluids are used by grouting contractors in the soil. [6]. These binders thoroughly disintegrate the soil structure and combine the soil particles in-situ to form a homogenous mass that eventually solidifies. The field of foundation stability benefits greatly from this ground modification/improvement of the soil, especially when it comes to treating load-bearing soils beneath both new and existing buildings, deeply im-permeating water-bearing soils, building tunnels, and reducing the movement of impacted soils and groundwater [7, 8, 28].

Electro osmosis: It is described as the electrochemical hardening that occurs when substances such as calcium chloride or sodium silicate are added to the anode. These substances seep into the earth in the cathode's direction, whereas the anode functions as a grout injection pipe [9, 10].

Soil improvement using mechanical methods

In this method, soil is being densified using rollers and vibrators by applying a compressive force on the given soil. These techniques are further classified below:

Stone Column: Stone columns can be built using the vibro-float method, which is also used to form sand compaction piles. Here, the sand-filled hollow steel compaction piles are replaced with stone piles, but the construction method for the stone columns is the same [11]. Similar to this, gravel can be used as the backfill material in the vibro-flotation technique. The steps for building a stone column using a vibro-float are displayed [12]. Stone columns can have stones ranging in size from 6 to 40 mm. Over the whole fill area, the stone columns' spacing can range from 1 to 3 meters. In general, it is considered that installed stone columns support the entire weight of the foundation and that intermediate ground plays no role [13].

Vibro Floatation: Vibro-compaction, also called vibro-floatation, is the process of using strong depth vibration to reorganize soil particles into a denser configuration. Granular soil particles can only go a few meters below ground level with a surface compactor or vibratory roller; deeper depths can only be reached by deep compaction techniques employing depth vibrators [14]. Sand grains that are loose are rearranged into a more compact state by the combined effects of vibration and water saturation caused by jetting. Vibrating probes that have been specially made are used for vibro compaction. There have been instances of both vertical and horizontal vibration modes in the past [15]. The probe is first inserted into the ground by both jetting and vibration. After the probe reaches the required depth of compaction, granular material, usually sand, is added from the ground surface to fill the void space created by the vibrator. A compacted radial zone of granular material is created [16]. Its applications are reduction of foundation settlements, reduction of risk of liquefaction due to seismic activity, permit construction on granular fills. Vibro compaction may be used as a ground improvement technique to support all type of structures from embankments to chemical plants. Vibro compaction is used to increase the bearing capacity of foundations and to reduce their settlements. Another application is the densification of sand to mitigate the liquefaction potential in earthquake prone zones. Vibro compaction method is not effective for soil having a percent finer more than about 15 to 20% [15, 16].

Micro Piles: Micro piles are deep foundation components made of threaded bar or high-strength, small-diameter steel casing. Micro-piles can support up to 5000 KN of weight in compression and have a small diameter of up to 300 mm. They guarantee minimal vibration or other damage to the foundation and subsoil and can be installed through almost any type of ground condition, obstruction, and foundation, as well as at any inclination. Micro piles can be designed under tension or compression as rock socketed piles or as soil frictional piles. Micro piles can be used to replace or repair existing foundations or as a foundation for brand-new buildings [15].

Soil Nailing: Steel tendons are drilled and grouted into the ground as part of this ground reinforcement procedure to form a composite mass [15]. Usually, a shotcrete facing is used. An in-situ method called "soil nailing" is used to stabilize, reinforce, and hold deep cuts and excavations in place [16]. It is not feasible to use soil nails in plastic clays and organic soil like peat. This method is cost-effective and less time consuming as compared to other conventional support methods [29].

Soil improvement without using admixtures

Admixtures are not necessary in some cases to stabilize the soil. A few of these methods are explained here:

Soil Replacement: It may be possible to remove inappropriate material and replace it with well-compacted suitable fill in soft soils with limited depth and thickness. Where it was discovered that the naturally occurring soils had a high moisture content and a low shear strength, replacement and removal were necessary. It might be necessary to implement subsurface drainage in the majority of these regions.

Vertical Drains: As water must travel a shorter distance through the permeable vertical drains out of the soil, vertical drains are used to accelerate consolidation and thereby increase the shear strength and bearing capacity of fine-grained soils, or impervious soils. The long-term settlement is thus constrained. They go by the names band drain and wick drain as well. Prefabricated vertical drains (PVD) and sand drains are the two most popular varieties of vertical drains [18].

Pre-Fabricated Vertical Drains (PVDs): Prefabricated vertical drains also known as wick drains consist of channelled synthetics core wrapped in geotextile fabric. They are flexible, durable, and inexpensive and have an advantage over sand drains is that they don't need drilling. The installation of prefabricated vertical drains is done.

Conclusion

From the study, it can be inferred that for weak soils that require treatment to make them suitable for construction, ground improvement techniques are a technically and financially feasible solution.

Many techniques have been tried and tested, and their application has been demonstrated recently for a range of projects, including ports, runways, industrial buildings, railroads, dams, slope stabilization, excavations, tunnels, and other infrastructure facilities. These soil stabilization techniques are applied globally to a range of soil types, including silty, clay, loose sand, and weak rocks.

In addition to the mentioned above, it is crucial to consider the cost of each specific method, the anticipated improvement in soil quality, and the equipment that is available before choosing any ground improvement technique. These factors are what ultimately determine which method is best. Although there are numerous approaches for improving the ground, there may not be one that works well for everyday use.

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