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Research Article

A Study on Handy Applications of Ground Soil Improvement

Vishal Arora* and Manoj Kumar

G.B.N. Govt. Polytechnic Nilokheri, Karnal, .Haryana

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Abstract

It is due to rapid growth of population, fast urbanization and more development of infrastructures like buildings, highways , railways and other structures in recent past years has resulted in reduction of availability of good quality of land. Therefore engineers have no choice left except to use soft and weak soils around by improving their strength by means of suitable modern ground improvement techniques for construction activities. At present the available ground improvement techniques are replacement of soil, vertical drains, stone columns, vibro compaction , dynamic compaction, soil reinforcement, vibro piers, in-situ densification, pre-loadings, grouting and stabilization using admixtures. The aim of these techniques are to increase the bearing capacity of soil and reduce the settlement. Ground improvement by reinforcing the soil is achieved by using fibers of steel, glass ,various polymers in the form of strips or grids and geosynthetics.

Keywords: *Geosynthetics, vertical drains, stone columns, vibro-compaction, dynamic compaction, soil reinforcement*

Introduction

The social, economic, cultural and industrial growth of any country depends heavily on its transportation system. The only mode which could give maximum service to one and all is transportation by highways and railways. As a result of development of infrastructures like buildings, highways, railways and other structures in recent past years has resulted in scarcity of good quality of land for construction projects. Therefore the engineers are bound to adopt inferior and weak soil for construction.

In present scenario the role of ground improvement techniques has become an important and crucial task for various construction projects. By ground improvement techniques the strength of the soil increases, its compressibility reduces and the performance under applied loading enhances. The expansive and collapsible soils are challenges to engineers due to their peculiar behavior of high swelling and shrinkage action. The construction of foundation on sanitary landfills, soft soils, organic soils and karst deposits are troublesome. It is to better to replace or bypass such type of soil strata by adopting suitable design of foundation and if not possible the ground improvement is the best solution for a such construction project site. This paper presents thorough study on various available modern ground improvement techniques and their applications in civil engineering in present scenario.

The prime purpose of this technique is to increase soil density by applying mechanical force in the form of static, vibratory rollers and plate vibrators as the case may be to achieve proper compaction. Compaction of the soil can be done easily if the soil fill material is well graded. Well graded soil being characterized by high uniformity coefficient Cu >15 and coefficient of curvature Cc between 1 and 3 can be compacted to greater density by rollers , tampers and other mechanical means. The optimum moisture content (OMC) should be determined and compaction should be done at or near the optimum moisture content for cohesive soils to achieve max dry density (MDD) with sheep foot rollers. However in case of cohesionless soils the compaction can be best achieved by vibrations.

Geosynthetics may be permeable or impermeable in nature depending on composition and its structure. The geosynthetics material can be used to perform different roles in different applications. It can be used as reinforcement, separation, filtration, protection , containment and confinement of soil to increase its bearing capacity.

Depending upon the requirement and site condition a Geocell reinforcement may also be used. This paper presents a thorough study on various available modern ground improvement techniques and their applications in civil engineering in present scenario. On the basis of long term performance results of various ground improvement techniques and its analysis, an efficient design can be developed and a suitable method of ground improvement technique may be adopted for a particular application.

Vibro-flotation

This technique can be effectively used for deposits of sands. In this method compaction is achieved by vibration and flooding the soil around it with water. This technique was invented around 1930 in Germany for treatment of

*Corresponding author: Vishal Arora

sandy soils. The equipment required for vibro-flotation is shown in Fig-1. It contains a vibro-float with a water sump, a crane, a front end loader, power supply etc. The vibro-float consists of a cylindrical penetrator tube about 0.38 meters in diameter and about 2.0 meter in length with an eccentric rotating weight inside the cylinder which is responsible for developing a horizontal vibratory motion. The weight can develop a horizontal centrifugal force of magnitude of about 100 KN at a speed of 1800 rpm.

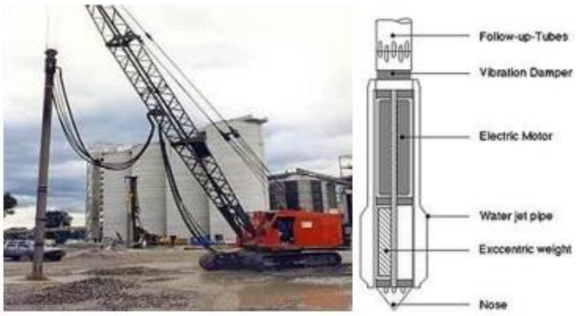

Fig.1 Vibro floatation equipmenta arrangement and Vibro Float

A typical vibro-float as shown in Fig-1,consists of two parts, the lower part is horizontally vibrating unit which is connected with upper part, a follow up pipe of adjustable length to suit compaction depth. The water pump provides water to sink the vibro-float into the ground by jetting action, as the vibro-float is lowered from the crane. Vibroflotation, sometimes also mentioned as vibro-compaction. Vibro-flotation may be defined as a process of rearrangement of soil grains into a denser state by use of powerful depth vibration. It creates a stable foundation soils by densifying loose sand. The loose sand grains are rearranged into a much compact state by combined action of vibration and water saturation by jetting.

Each compaction sequence as shown in Fig-2, involves four basic steps, as mentioned belowi. The vibro-float probe is suspended from the crane, and is positioned over the ground at the spot to be compacted. Its lower jet is then fully opened. ii. Water is pumped in faster than it can drain away into the subsoil. This creates a momentary “quick” condition beneath the jet, which permits the vibro-float to sink of its own weight and vibrations. iii. Water is switched from the lower to the top jets, and pressure is reduced enough to allow water to be returned to the surface, eliminating any arching of the backfill material and facilitating the continuous feed of backfill. iv. Compaction takes place during 0.3 m per minute lifts, which return the vibro-float to the surface,up from the bottom of soil deposit being compacted. Thus raising the vibrator step by step and simultaneously backfilling with sand, the entire deposit of sand can be compacted into a hard core.

The depth up to which a vibro-float can cause compaction is about 30 meters. The maximum compaction depth depends on the capacity of the crane to pull out vibro-float from the ground, soil type and backfill material. The suitability of the backfill material depends upon the gradation.

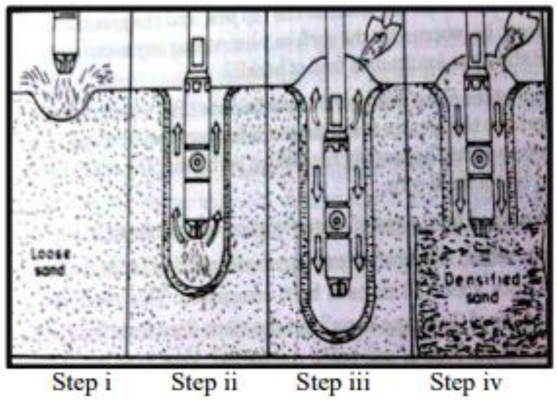

Fig.2 Steps involved in Vibro floatation process

On the basis of suitability number the quality of backfill material can be described as excellent, good and bad, as shown in table -1 below-

Table 1 Backfill Evaluation Criteria

S. no.	Suitability Number	Rating Quality
1	0-10	Excellent
2	10-20	Good
3	20-30	Fair
4	30-50	Poor
5	>50	Unsuitable

Very loose sand below the water table can be best compacted by this method. Relative density up to 85% can be achieved. However with increase in silt and clay content in the soil layer the depth of compaction reduces. It is only due to finer particles and organics damping out vibrations, sticks the sand particles together or filling the voids between the particles, thereby restricting the movement of particles necessary for densification. Clay layers present in in-situ soil also reduce the zone of compaction. In soft cohesive soils the vibro-flotation technique is used with gravel as backfill material.

Heavy weight compaction

In this method loose soils are compacted by repeated dropping of heavy weight on the ground surface, so as to cause compaction of soil up to sufficient depths. This method is very simple, can be used for both cohesionless and cohesive soils as well. This method is also known as deep dynamic compaction or deep dynamic consolidation method.

A crane is used to lift a heavy concrete or steel block weighing up to 500 KN and up to a height of 40 to 50 meters, from this height it is allowed to fall freely on to the ground surface. As a result of impact of falling weight on ground will cause a deep pit on the surface as shown in Fig-3. This process of falling weight is then repeated either at the same location or over other parts of the area to be compacted turn by turn, as to cover entire area. Top soil is then leveled and compacted in the same manner by using some lighter weight.

Fig.3 Deep dynamic compaction

Sand compaction piles

For construction of sand compaction pile a hollow steel pile with bottom closed by a collapsible plate, is driven up to the required depth through the loose fill, The hollow pipe is then filled with sand and the pipe is withdrawn while the air pressure is directed against the inside sand from the top. The bottom plate which is of collapsible type in nature, opens during the withdrawal, and sand from pipe backfills the hollow space created earlier during driving of the pile. The in-situ soil is densified while the pipe is being withdrawn and the sand backfill prevents the soil surrounding the compaction pipe from collapsing as the pipe is withdrawn.

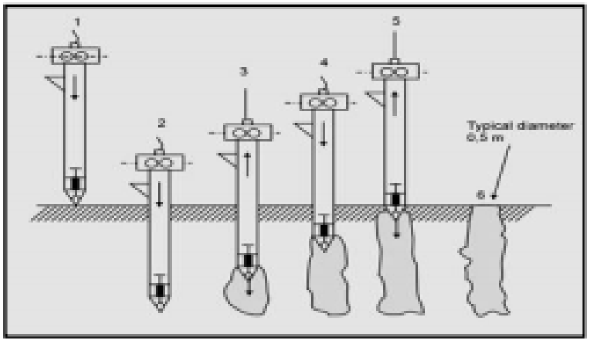

Fig.4 Formation of sand compaction piles

Blending

Sometimes soil deposits show skip grading i.e. the particle size distribution (PSD) curve possesses a horizontal portion, reflecting deficiency of particles of some particular size. The particles of missing sizes will have to be added to reduce their void ratio. This addition of missing size of particles is known as blending and is often used in highway projects. Similarly cohesionless soils (uniformly graded) are usually mixed with cohesive soils , as to enable them to be compacted easily with conventional road rollers. This is also known as blending. The main objective of the blending is to reduce the void ratio. In the field it is achieved by obtaining particle size distribution (PSD) curve with high coefficient of uniformity (Cu) after blending.

Blast Densification

It is a ground improvement technique used for loose cohesionless soil to densify the same. It increases the density of loose granular soil irrespective of its position above or below the ground water table. Due to impact of explosive waves soil temporarily gets liquefied and excess pore water pressure gets dissipated causing rearrangement in soil grains to achieve higher relative density. It is suitable to treat soil up to 40 meters depth. At greater depth more charge is required for similar action.

The basic principle of this method states that soil is compacted due to shock waves and vibration generated by blasting. This method is also called explosive compaction. It is economical and can treat large depths at low cost. The soil types treated by this method range from silt tailings to gravel cobbles and boulders.

Stabilization by Pre-loading Method

The deposits of oft fine grained silts and clays, organic soils, loose silts, and sandy soils and even rubbish can be stabilized by pre-loading method. In this method a load is placed on the area having the weak compressible or loose surface strata , usually after spreading a blanket layer of sand over the site as shown in Fig- 6&7. This blanket layer acts as a drainage layer of high permeability as well as a levelling course. The surcharge load over the blanket layer increases the stress in the soil layer below it, thereby increasing the neutral stress (pore water pressure).

The increase in the neutral stress initiates the consolidation process. And with the passage of time the neutral stress gets dissipated with expulsion of water. This causes a corresponding increase in the effective stress between the soil particles. This increase in effective stress changes the alignment of soil solids and consequently decreases the void ratio. Thus there occurs a volume change and increase in shear strength of the deposit. The weak compressible soil layer hence becomes stronger and a good bearing strata.

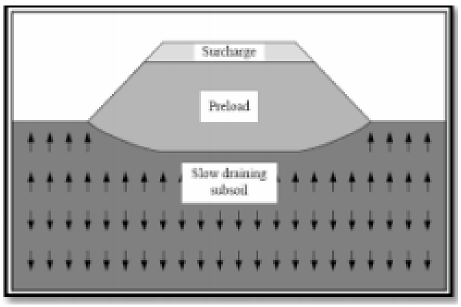

Fig.5 Pre-loading Method

Latest trends in ground improvement

The improvement in ground properties can be done by certain methods. By using Vibro-flotation the density of the soil can be increased by virtue of powerful depth vibrators. By use of vacuum pump the properties soft soil can be improved by consolidation. The pore water can be removed from the soil over a passage of time by pre-loading technique. By passing electric current in the ground results in heating of soil particles to form a crystalline product.

The pore water is converted into ice by freezing action of ground which will result in increase their combined strength of ground and will make them impervious. Bearing capacity of the soil is increased by Vibro-replacement stone columns whereas the soil is displaced by Vibro-displacement method. Water flows through fine grained soils by virtue of Electro-osmosis which is responsible for Electro kinetics stabilization of soil. In sloping walls, dams etc. the reinforced soil is used. The reinforced soil mass is created by stabilizing earth structure mechanically.

The Geosynthetics, geogrids are also used for this purpose. The shear strength of the in-situ soil is increased by soil nailing and restrains its displacement. The structural support to the existing foundation can be given by repair and replacement using micropiles. To increase its rigidity grouting is done under pressure by using pumpable materials. The technique of jet grouting is advance and is speedy too as compared to general grouting.

Conclusion

From the study it can be concluded that the Ground Improvement Techniques is a technically viable and cost effective solution for soils which are weak in strength and treatment is to be done in order to make them suitable for construction. The use of various techniques have been tested and its use has been proven in the recent past years for a variety of projects like highways, ports, runways, industrial structures, railways, dams, slope stabilization, excavations, tunnelling and other infrastructure facilities. These method of soil stabilization have been used world-wide for variety of soils like loose sand, silts, clays and weak rocks.

In addition to above, before selecting any ground improvement technique it is important to evaluate the cost of each particular method and expected soil improvement, available equipments, which are the decisive factors for the selection of appropriate method. There are so many methods available for ground improvement but still a method which suits for routine application, perhaps not available.

For future development the following possibility should be explored:

1. Best incorporation sustainability consideration in suitable ground improvement method selection on the basis of green construction and life cycle cost analysis.
2. Development of codes and legislation.
3. Study on adverse environmental impacts due the effect of adding things to the ground.
4. Development of a data bank with the description of incidents, variability of soil and material properties and accidents for a more deep understanding of ground improvement.
5. Development of improved and more reliable method of ground improvement with adequate quality control.

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