Sandy Soils Improvement Techniques and Its Applications

Vishal Arora[1]* Manoj Kumar[2]

[1]Lecturer in Civil Engineering, Department G.B.N. Govt. Polytechnic, Nilokheri, Karnal, Haryana

[2]Lecturer in Civil Engineering, Department G.B.N. Govt. Polytechnic, Nilokheri, Karnal, Haryana

***Abstract* – In recent years rapid development of infrastructures in metro cities compounded with scarcity of useful land and compelled the engineers to improve the properties of soil to bear the load transferred by the infrastructure e.g Buildings, bridges, roadways railways etc. The engineering techniques of ground improvement are removal and replacement, pre-compression, vertical drains, in-situ densification, grouting, stabilization using admixtures and reinforcement.**

The purpose of these techniques to increase bearing capacity of soil and reduce the settlement to a considerable extent. The one of the method among ground improvement techniques is reinforcing the soil with materials like steel, stainless steel, aluminum, fibers, fiber glass, nylon, polyster, polyamides in the form of other strips or grids and Geotextiles. The Primary purpose of reinforcing a soil mass is to improve its stability, increasing its bearing capacity and reduce Settlements and Lateral deformations. Geotextiles and geomembranes, broadly speaking are synthetic fibres used to stabilize structures built on soil. The new widely accepted generic term for these non-natural materials is Geosynthetics.

Keywords – Ground improvement, Geosynthetics, Vibrocompaction, Prefabricated Vertical Drains, Soil Reinforcement

---♦-------------------------------------

INTRODUCTION

Ground improvement techniques are given the utmost importance in present days to adapt week ground/soil into the appropriate competent stable ground for different civil engineering applications.

It started with Henri Vidal (1960) and became familiar with the pioneer work of Binquet and Lee. Ground improvement techniques are recommended in difficult ground conditions as mechanical properties are not adequate to bear the superimposed load of infrastructure to be built, swelling and shrinkage property more pronounced, collapsible soils, soft soils , organic soils and peaty soils, karst deposits with sinkhole formations, foundations on dumps and sanitary landfills, handling dredged materials for foundation beds, handling hazardous materials in contact with soils, using of old mine pits as site for proposed infrastructure.

When a project site come across any of the above difficult conditions, possible alternative solutions may be one of among as avoid the particular site; design the planned structure (flexible/rigid) accordingly, remove and replace unsuitable soils, attempt to modify existing ground, enable cost effective foundation design, reduce the effects of contaminated soils, ensure sustainability in construction projects using ground improvement techniques. While it may not be immediately apparent, ground improvement methods have made considerable advances since today's commonly practiced techniques began to develop in the 20th century however most techniques have gone through changes. This paper presents a review on research and development in the field of ground improvement.

Geosynthetics include permeable and impermeable materials that are either of knitted, woven, or non-woven nature, as well as polymer grids and meshes. The role of geosynthetic material varies in different application as it can serve as reinforcement, separation, filtration, protection, containment, fluid transmission and confinement of soil to improve bearing capacity.

Geocell reinforcement is a recently developed technique in the area of soil reinforcement having a three dimensional, polymeric, honeycomb like structure of cells made out of geo-grids inter connected at joints. Selection processes for ground improvement methodologies, improved analysis, and knowledge of long term performance and understanding of effects of variability are required to develop more efficient designs. This paper presents a review on recent development in ground improvement techniques.

MECHANICAL IMPROVEMENT TECHNIQUES

In this method soil density is increased by the application of mechanical force, including compaction of surface layers by static vibratory such as compact roller and plate vibrators. This technique is further classified as:- a. Dynamic Compaction b. Vibro-Compaction c. Compaction Grouting d. Pre loading and Pre-fabricated Vertical Drains e. Blast densification

A. Development of Dynamic Compaction

This technique was invented and promoted by Louis Menard as early as 1969 but it was not until 29 May 1970 that he officially patented his invention in France. The concept of this technique is improving the mechanical properties of the soil by transmitting high energy impacts to the soil by dropping a heavy weight called pounder from a significant height. When feasible, dynamic compaction is probably the most favorite ground improvement technique in granular soils as it is usually the most economical soil improvement solution (Mitchell, 1981).

Depth of influence or improvement is the depth where there are limited or practically insignificant amounts of improvement in the soil. Menard and Broise (1975) developed an empirical equation in which the depth of influence, D, was a function of the square root of the impact energy; i.e. the product of the pounder weight (in metric tons) by the drop height (in metres). Later and based on further site experiences others introduced a coefficient less than unity to the original equation and Varaksin (Chu et al., 2009) has further refined the relationship by introducing drop type and energy function coefficients. Hamidi et al. (2011a) have reviewed the equipment advances of dynamic compaction rigs. Menard performed his first dynamic compaction projects using 80 kN pounders that were dropped from 10 m. He was soon able to identify heavy duty cranes that were capable of efficiently lifting and dropping pounders weighing up to about 150 kN using a single cable line.

Menard then developed and manufactured his own rigs that were able to lift 250 and more than 1,700 kN pounders. As much as these special rigs had their applications, they were specifically produced, their numbers were limited and they could not be manufactured commercially or in great numbers. However, the introduction of a new generation of cranes that are able to lift pounders using two single cable lines has now increased lift capacity commercially to 250 kN. The introduction of these rigs was able to increase pounder lift capacity; however it is still possible to improve the efficiency of impact energy by dropping the pounder in free fall. Thus, the next major innovation in dynamic compaction was the development of the Menard Accelerated Release System (MARS) which is able to release the pounder from the lifting device as the pseudo free fall commences. In this method Digital monitoring instruments are now able to record the coordinates of the impact point, drop height, number of drops per point and impact velocity. This enables the engineer to improve quality assurance and optimization of work parameters. This technique is most suitable for densification of loose granular soils.

Fig.1 Dynamic Compaction

B. Development of Vibro-compaction

This technique involves densification of granular soil using a vibratory probe inserted into ground. It is a deep compaction technique that was invented in the mid-1930s in Germany for treating sandy soils. In this technique an electric or hydraulic vibrating unit called a vibroflot or vibro-probe penetrates the ground and the loose sands and causes in enhancement of density. Although the appearance of vibroflots have not changed much during the past seven decades and most equipment would seem very similar to the untrained eye, today specialist ground improvement companies manufacture vibro-probes with different capabilities. Vibration frequencies are now closer to the soil's natural frequency and the power range of the plant allows specific uses of each machine. Vibro-compaction is successful in loose sand soils typically with an original SPT value of 5 to 10 near the surface and not applicable to clays. Relative density of up to 85% can be achieved.

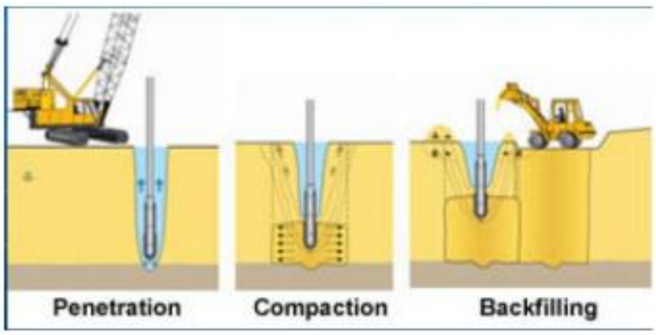

Fig.2 Process Of Vibro Compaction

C. Development of Compaction Grouting

Compaction grouting is a ground treatment technique that involves injection of a thick-consistency soil-cement grout under pressure into the soil mass, consolidating, and thereby increases density of surrounding soils in-situ. The injected grout mass occupies void space created by pressure-densification. Pump pressure, as transmitted through low-mobility grout, produces compaction by displacing soil at depth until resisted by the weight of overlying soils.

Compaction Grouting When injected into very dense soils or bedrock, compaction grout remains somewhat confined, since the surrounding material is quite dense. However when injected into under-consolidated or poorly-compacted soils, grout is able to "push" these materials aside. When grouting treatment is applied on a grid pattern, the result is improved compaction of displaced soils and greater uniformity of the treated soil mass. As a secondary benefit, the resulting grout columns add strength in the vertical axis, as typical grout compressive strengths exceed those of the surrounding soils.

Compaction grouting applications include densification of foundation soils, raising and relieving of structures and foundation elements, mitigation of liquefaction potential, augmentation of pile capacity and pile repair, and densification of utility trench backfill soils. The method has also been used to support deep excavation into soft ground for a case in Shanghai (Liu et al 2005). A few more examples are given by Welsh and Burke (2000). An alternative compaction grouting technique has also been proposed by Naudts and Van Impe (2000) in which geo-textile bags are used. In adopting this method, regular sleeve pipes are installed to the required depth. Geo-textile bags are strapped straddling all or some of the sleeves. The geo-textile bags are inflated via a double packer with balanced, stable, low viscosity cement based suspension grout with high resistance against pressure filtration.

Several bags (on different pipes) are inflated at the same time. The inflation process is done in stages to allow the water to slowly (pressure) filtrate through the geo-textile bags. During each grouting stage the pressure is systematically increased. The spacing between the grout pipes has to be such that the soils are subjected to vertical stresses in excess of those they will eventually be subjected to. The volume reduction of the surrounding soils under the grouting pressure, as well as the influence radius of the compaction grouting can be mathematically estimated with the method described by Naudts and Van Impe (2000). This in turn dictates the spacing between the grout pipes.

D. Soil Modification by Pre-fabricated Vertical Drains

This method increases the bearing capacity and reduces the compressibility of weak ground and it is achieved by placing temporary surcharge on the ground. Surcharge generally more than the expected bearing capacity. It is most effective for soft cohesive ground. The process may be speed up by vertical sand drains/prefabricated vertical drains. These drains are installed in order to accelerate settlement and gain in strength of soft cohesive soil. Vertical drains accelerate primary consolidation only.

As significant water movement is associated with it. Secondary consolidation causes only very small amount of water to drain from soil; Secondary settlement is not speeded up by vertical drains. Only relatively impermeable type of soil is benefited from vertical drains. Soils which are more permeable will consolidate under surcharge. Vertical drains are effective where a clay deposit contain many horizontal sand or silt lenses.

Fig.3 Compaction Grouting

E. Soil Modification by blast densification

Blast-densification is a ground improvement technique for densifying loose, relatively clean, cohesion less soils. It increases the density of loose granular deposits, above or below the water table. The explosive wave temporarily liquefies the soil, causing the soil particles to rearrange to a higher relative density as excess pore pressure dissipates. It has been used to treat soils to depths of up to 40m. As depth increases, the size of the charge necessary to destroy the soil structure and liquefy the soil increases. Excess pore pressure and settlement due to explosion are related to the ratio Nh = W 1/3/R ,where Nh= Hopkin's number, W= weight of explosives, equivalent kilograms of TNT and R= radial distance from point of explosion, m.

If Nh is less and in the range of 0.09 to 0.15, liquefaction does not occur and the equation can be used to estimate safe distance from explosion. Example Nh = 0.12 and W= 10kg Radial distance from point of explosion, R = 17.95m The use of blasting for the densification of granular soil has been developed for many years. The principle of the method is to generate settlement of granular soil ground or fill by causing the soil to liquefy or be compacted using the shock waves and vibration generated by blasting. This method was used in the past mainly for mitigation of liquefaction in hydraulically placed sand fill. Therefore, the method has also been called explosive compaction. The development and application of this method up to the early 80s were summarised by Mitchell (1981).

Explosive compaction has the advantage of low cost and ease of treating large depths. However, the method has not been widely accepted mainly because it is still based on experience rather than theory. Some field studies (Charlie et al 1992; Gandhi et al. 1998; Gohl et al. 1998; 2000) have been carried out in order to understand better the blasting process. Theoretical analyses and numerical modelling using cavity expansion theories and blasting mechanics have also been done (Henrch 1979; Wu 1995; Van Court and Mitchell 1995; Gohl et al. 1998) to improve the design and analysis. In recent years, explosive compaction has also been applied to the mining sector to shake down tailings ponds for tailings consisting of essentially non-plastic silt and sand-size particles. In this way, the volume of the existing tailings is reduced, which increases the storage capacity of the tailings impoundment and minimizes the need to raise the crest elevation of the tailings containment dike. The soil types treated by the explosive compaction method range from silt tailings to gravel cobbles and boulders.

CONCLUSIONS

This paper has attempted to offer a review of the recent development in of ground improvement techniques which are widely used in the field of geotechnical engineering and will play a major role in the field and earthwork construction projects of many types in the years ahead. As described many technologies are now available, some that are very old and some that are still developing and emerging, but perhaps not yet quite ready for routine application. Some of the further research area among the key problems is:-

a. How to best incorporate sustainability considerations in ground improvement method selection and implementation giving consideration to embodied energy, carbon emissions, and life cycle costs.

b. How to improve and simplify constitutive modeling.

c. Development of practical, economical and environmentally safe biogeochemical methods for soil stabilization and liquefaction risk mitigation.

d. Development of databases for variability of soil and material parameters required in the design of ground improvement.

e. Development of improved and more reliable methods for evaluating the long term durability of soils mixed with binder.

f. Understanding creep mechanisms in soils and interaction of creep with semi-rigid inclusions.

It is anticipated that with continued research and field experience in addressing challenges such as above, the subdiscipline of ground improvement will continue its development and importance as a critical component of successful geotechnical engineering and construction.

REFERENCES

Binquet J.& Lee, K.L. (2012). Bearing capacity test on reinforced earth slabs‖, Journal of Geotechnical Engineering Division, ASCE, 101(12), pp. 1241-1255.

Bo, M.W., Chu, J., Low, B.K. & Choa, V. (2003). Soil Improvement Prefabricated Vertical Drain Technique‖, Thomson Learning.

Charlie, W.A., Jacobs, P.J., & Doehring, D.O. (2012). Blastinginduced liquefaction of an alluvial sand deposit‖ Geotechnical Testing Journal, ASTM, 15(1): pp. 14-23.

Guido, V.A., Chang, D.K. & Sweeney, M.A. (2006). Comparison of geogrid and geotextile reinforced earth slabs‖,Canadian Geotechnical Journal (23), pp. 435-440.

Hausmann M. (2010). Engineering principles of Ground modification‖, Mc Graw-Hill Publications.

Karol, R.H. (2003). Chemical Grouting and Soil Stabilization‖, 3rd: CRC Press.

Liu J. (2003). Compensation grouting to reduce settlement of buildings during an adjacent deep excavation‖, Proc. 3rd Int. Conf. on Grouting and Ground Treatment, Geotechnical Special Publication120, ASCE, New Orleans, Louisiana, 2: pp. 837-844.

Mitchell, J.K., & Katti R.K. (2001). Soil Improvement‖ - State of the Art Report. 10th ICSMFE, Stockholm, 4: pp. 509-565.

Van Impe, W. F. (2009). Soil improvement techniques and theirEvolution‖, Taylor & Francis.

Varaksin, S.(2011). Recent development in soil improvement techniques and their practical applications‖, Solcompact Sols/Soils, Techniques Louis Menard, 15, rue des Sablons, Paris, pp. 38/39-2011.

Welsh, J.P., & Burke, G.K. (2000). Advances in grouting technology‖, Proceedings of GeoEng 2000. Melbourne.

Corresponding Author

Vishal Arora*

Lecturer in Civil Engineering, Department G.B.N. Govt. Polytechnic, Nilokheri, Karnal, Haryana

E-Mail – vikas.pandey94@gmail.com