A Review: Ground Improvement Techniques

Dr. Vijay Singh Rawat[1], Dr. R. Divahar[2], Mr. Chimdi Gadafa[3], Shreyance Sharma[4]
[1, 2, 3] Dept of Civil Engineering
[4]HOD, Dept of Civil Engineering
[1, 2, 3] School of Civil Engineering & Architecture
Adama Science and Technology University
[4]Aryan Polytechnic College, Chachiyawas, Ajmer, Raj. India

***Abstract**- Vast areas covered with thick layers of fills or with layers of soft clay deposits are not suitable, for the construction of a foundation. With the increasing size of urban areas and industrial zones it is necessary to consider the possibilities of realizing foundations on these areas. The term ground modification has been developed by GKN Hayward-Baker to describe the specialty that encompasses the full range of techniques now available to density or otherwise improve the ground as an integral part of the construction system. In short, ground modification is the in-place controlled improvement of ground materials to form part of the geotechnical construction system. 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, insitu 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. Ground improvement techniques are normally preferred for economic considerations, Ground improvement techniques are used increasingly for new projects to allow utilization of site with poor subsurface conditions. Previously, these poor soils where considered as economically unjustifiable or technically not feasible and are often replaced with an engineered fill or location of the project is changed. In short, ground improvement is executed to increase the bearing capacity, reduce the magnitude of settlements and the time. The following methods will be discussed: Grouting, Deep vibro-techniques, Dynamic compaction, Stone Columns, Soil Nails and Lime and lime/cement columns. These techniques have a wide range of applicability from coarse grained soils to fine grained soils. Depending upon the loading conditions and nature of soil, a suitable technique which is also economical needs to be adopted. This paper gives the concept and theory of a few ground improvement techniques and describes the practical application of these techniques along with a case history for each of the techniques.*

I. INTRODUCTION

The different construction materials, methods, techniques, and processes, one common bond remains among all projects undertaken. The majority of all Of man'-construction has been done on, in, or with soil. With the increase in environmental concerns and availability of suitable construction sites decreasing, the need to utilize what were once thought of as poor soil areas for construction is increasing. With the advent of ground modification techniques, (past, present, and future) the use of nature's most abundant building material -, soil, can be extended.

How does project engineering choose a ground improvement technique(s) to implement?

- Case studies
- Numerical & statistical analyses
- Laboratory tests on soil specimens QA/QC)
- Benefit vs. cost analysis
- Construct ability issues + engineering judgment

Purpose:

- Increase confidence in ground improvement techniques.
- Before using any of the ground improvement techniques the sub-soil must be investigate.

Sub-soil investigation

Sub-soil investigation shall be done describing the character, nature, load bearing capacity and settlement capacity of the soil before constructing a new building and structure or for alteration of the foundation of an existing structure. The aims of a geotechnical investigation are to establish the soil, rock and groundwater conditions, to determine the properties of the soil and rock, and to gather additional relevant knowledge about the site. Careful collection, recording and interpretation of geotechnical information shall be made. This information shall include ground conditions, geology, geomorphology, seismicity and hydrology, as relevant. Indications of the variability of the ground shall be taken into account.

BEARING CAPACITY OF THE SOIL

When physical characteristics such as cohesion, angle of internal friction, density etc. are available, the bearing capacity shall be calculated from stability considerations. Established bearing capacity equations shall be used for calculating bearing capacity. A factor of safety of between 2.0 to 3.0 (depending on the extent of soil exploration, quality control and monitoring of construction) shall be adopted to obtain allowable bearing pressure when dead load and normal live load is used. Thirty three percent overstressing above allowable pressure shall be allowed in case of design considering wind or seismic loading. Allowable load shall also limit settlement between supporting elements to a tolerable limit. A significant portion of the overall project cost is often spent on Foundations Systems and Earthwork Compaction. Particularly on sites with poor or marginal soils, there is a need to look into Ground Improvement in order to provide for economical foundation or earthworks. I. Grouting generally is used to fill voids in the ground (fissures and porous structures) with the aim to increase resistance against deformation, to supply cohesion, shear-strength and uniaxial compressive strength or finally –and even more frequently – to reduce conductivity and interconnected porosity in an aquifer. Grouting uses liquids which are injected under pressure into the pores and fissures of the ground (sediments and rock). Liquid grout mixes consist of mortar, particulate suspensions, aqueous solutions and chemical products like polyurethane, acrylate or epoxy. Piston or screw-feed pumps deliver grout through open boreholes into fissures in rock, through lances, perforated pipes and packered or sleeved pipes into sedimentary soils. By displacing gas or groundwater, these fluids fill pores and fissures in the ground and thus – after setting and hardening – attribute new properties to the subsoil.

A. Compaction Grouting

In the early 1980s compaction grouting was used for the first time as a site improvement technique for new construction. It was used in conjunction with dynamic deep compaction (DDC) to density the soil beneath two 600 MW coal-fired electrical generating units in Florida: Since that time its use as a site improvement tool has spread further. Compaction grout, grout injection with less than one inch (25 mm) slump. Normally a soil cement with sufficient silt sizes to provide plasticity together with sufficient sand sizes to develop internal friction. The grout generally does not enter soil pores but remains in a homogenous mass that gives controlled displacement to compact loose soils, gives controlled displacement for lifting of structures, or both.

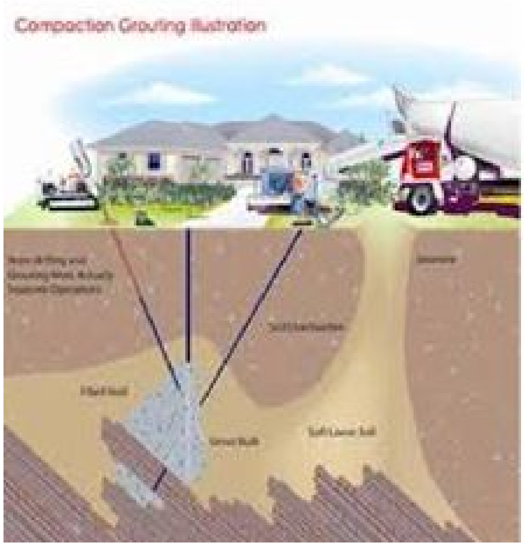

Fig.1 compaction grouting

B. Chemical Grouting Chemical grouting is the process of injecting a chemically reactive solution that behaves as a fluid but reacts after a predetermined time to form a solid, semisolid, or gel. Chemical grouting requires specially designed grouting equipment in that the reactive solution is often formed by proportioning the reacting liquids in an on-line continuous mixer. Typically, no allowance is made in chemical-grouting plants for particulate materials suspended in a liquid. Further, the materials used in the pumps and mixers are specifically selected to be nonreactive with the chemicals being mixed and pumped.

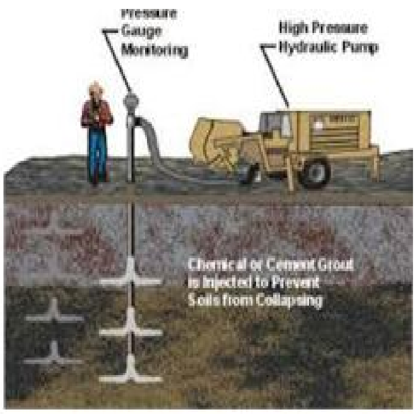

Fig.2 chemical grouting

C. **Jet Grouting**

The earliest patent regarding jet grouting was applied for in England in the 1950s; however, the real practical development of jet grouting took place for the first time in Japan. Of all forms of ground improvement systems, jet grouting must be regarded as one of the most versatile. With this technique it is possible to strengthen cut-off groundwater and provide structural rigidity with a single application. It can also be regarded as one of the most technically demanding of ground improvement systems requiring equally both technical excellence in design and construction because failure of either component will result in failure of the product. Jet grouting method is used to improve soil strength parameters and at the same time to create an impervious layer. This method involves a combination of the following three consecutive processes: • break-up of the soil structure by a fluid injected into the soil under high pressure; • extraction of the surplus spoils to the surface; • mixing of the soil with cement grout, resulting in the cement-and-soil mixture.

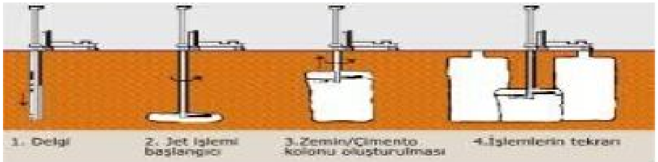

Fig. 3 jet grouting

II. DEEP VIBRO TECHNIQUES

Vibro compaction is probably the oldest dynamic deep compaction method in existence. It was introduced and developed to maturity by the Johann Keller Company in 1936, which enabled the compaction of non-cohesive soils to be performed with excellent results. A detailed description of the method from its beginnings up to the pre-war period is given by Schneider (1938) and by Greenwood (1976) and Kirsch (1993) for the period thereafter. The vibrator shell is constructed of steel pipe, forming a cylinder. Eccentric weight in the lower section is powered by a motor at the top end of a vertical shaft within the vibrator. Energy for the motor is supplied through the extension tubes. The rotational movement of the eccentric weights causes vibrations of the vibrator. The vibratory energy is transferred from the vibrator casing to the surrounding soil. This energy affects the surrounding soil without being dependent on the vibrator's depth of operation. A vibration damping device betweenthe vibrator and extension tubes prevents the vibratory energy from being transmitted to the extension tubes. Supply pipes for water and air (optional) are also enclosed in the extension tubes. The pipes can deliver their payload through the vibrator tip as well as through special areas of the extension tubes to aid the ground penetration action of the vibrator.

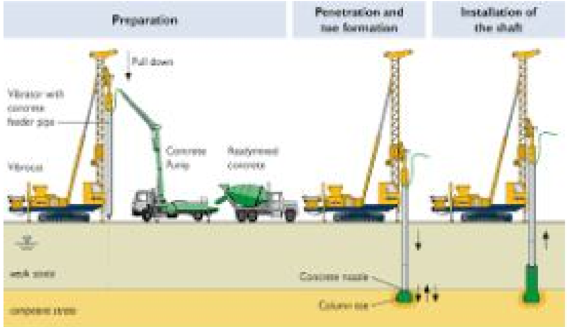

Fig.4 deep- vibero technique

III. DYNAMIC COMPACTION

The Dynamic Compaction technology, also known as the method of dynamic consolidation, is a technology invented and developed by Menard Company. Since the late 1960s the Dynamic Compaction has been developed on the numerous sites all over the world for various soil conditions and for a variety of applications such as: roads, airports, large halls and more. This technology patented by Louis Menard was extensively tested and optimized hence its safe and economic application today. Dynamic compaction strengthens weak soils by controlled high-energy tamping. The reaction of soils during dynamic compaction treatment varies with soil type and energy input. A comprehensive understanding of soil behavior, combined with experience of the technique, is vital to successful improvement of the ground. Given this understanding, dynamic compaction is capable of achieving significant improvement to substantial depth, often with considerable economy when compared to other geotechnical solutions.

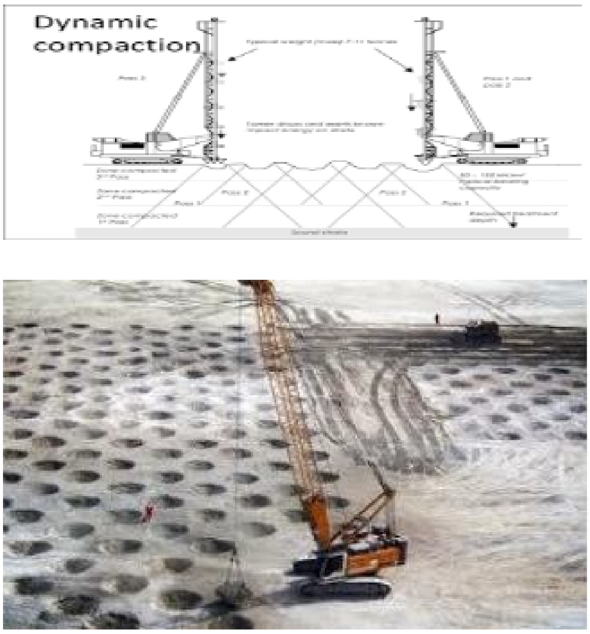

Fig.5 dynamic compaction

V. STONE COLUMN

The stone column technique was adopted in European countries in the early 1960s. A stone column is one of the soil stabilizing methods that is used to increase strength, decrease the compressibility of soft and loose fine graded soils, accelerate a consolidation effect and reduce the liquefaction potential of soils. The columns consist of compacted gravel or crushed stone arranged by a vibrator. The stone can be compacted with impact methods, such as with a falling weight or an impact compactor or with a vibroflot, the more common method. The method is used to increase bearing capacity (up to 5 to 10 kef or 240 to 480 Kpa), reduce foundation settlements, improve slope stability, reduce seismic subsidence, reduce lateral spreading and liquefaction potential, permit construction on loose/soft fills, and pre-collapse.

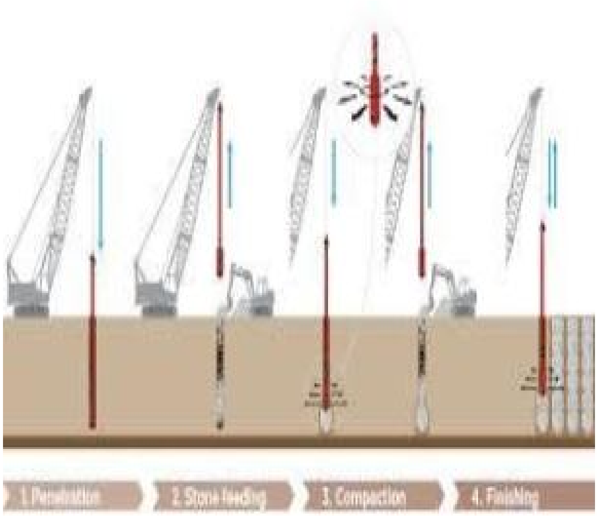

Fig.6 process of stone column

V. LIME AND LIME/CEMENT COLUMNS

Lime and lime cement columns are columns of stabilized clay 0.5–0.6 m in diameter. In lime stabilization, finely milled, burnt lime is mixed with soft clay using a lime column machine. In lime/cement columns standard Portland cement is added to the lime. Normally the proportions of lime/cement in percent per weight are 50/50 in lime/cement columns. In clays that react positively to mixing the soft clay is converted into a firm clay resembling a dry crust. The soft clay outside the stabilized zone is practically unaffected. The shear strength and compression modulus of lime and lime/cement columns are considerably higher than in the un stabilized clay. Columns improve the bearing capacity of soft clay according to the spacing between the columns. The clay mixed with lime and cement in the columns is not homogeneous. When mixed with lime and cement, lumps of stabilized clay are formed. The shear strength in the joints between the lumps is lower than within the lumps. Lime-cement columns can be made with two different methods; the dry-mixing method and the modified dry-mixing method. The dry mixing method no water is added; instead water in the soil is consumed for the process. Therefore this method only can be used in soils with relatively high water content, e.g. in clay and silt.

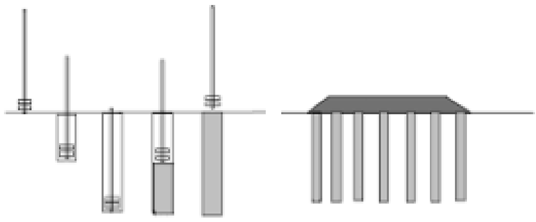

Fig. 7 The procedure when installing a lime cement column

VI. CONCLUSIONS

All of the above ground Improvement techniques forms technically sound and cost effective solution where the sub soils are weak and needs to be treated to enable the intended construction. Its applicability has been proven in the recent past for a wide range of structures such as roads, runways, ports, power plants, railways, dams, slope stabilization, excavations, tunneling and other infrastructure facilities.These techniques have been used all over the world for a wide range of soils starting from loose sands, silts, marine clays to weak rocks. Based on the soil conditions, loading intensity and intended performance, an appropriate ground improvement technique can be designed to attain the desired performance. Engineers must be aware of the capabilities and limitations of available liquefaction remediation.

REFERENCE

[1] “Ground Engineering”. The Institute of Civil Engineers, London, 1970.

[2] Rawlings,C G, Hellawell,E. E. and Kilkenny,W. M.(2000). “Grouting For Ground Engineering “, CIRIA, LONDON

[3] Koerner, R. M. (1990). “Designing With Geosynthetics”, PRENTICE-HALL .

[4] Wood, I. R. (1982). “Vertical Drains”, THOMAS TELFORD.

[5] Davics, M. C. and Schlosser, F. (1997). “Ground Improvement Geosystems”, THOMAS TELFORD, London

[6] Hausmann,M(1990),―Engineering principles of Ground modification‖, McGrawHill Publications.
[7] Binquet,J.& Lee, K.L. (1975), ―Bearing capacity test on reinforced earth slabs‖, Journal of Geotechnical Engineering Division, ASCE, 101(12), 1241-1255.
[8] Guido, V.A., Chang, D.K. & Sweeney, M.A. (1986), Comparison of geogrid and geotextile reinforced earth slabs‖,Canadian Geotechnical Journal (23), 435-440.
[9] Varaksin, S.(1981), Recent development in soil improvement techniques and their practical applications‖, Solcompact Sols/Soils,Techniques Louis Menard, 15, rue des Sablons, Paris, 38/391981.
[10] 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: 837-844.
[11] Welsh, J.P., & Burke, G.K. (2000), ―Advances in grouting technology‖, Proceedings of GeoEng 2000. Melbourne.