International Journal of Inventive Engineering and Sciences (IJIES)
ISSN: 2319–9598, Volume-2 Issue-2, January 2014

Ground Improvement Techniques

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Abstract— Ground Improvement techniques are often used to improve sub soil properties in terms of their bearing capacity, shear strength, settlement characteristics, drainage, etc. 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.
Keywords

I. INTRODUCTION

Ground improvement, is the modification of existing site foundation soils to provide better performance under design and/or operational loading conditions. Ground improvement techniques are used increasingly for new projects to allow utilization of sites with poor subsurface conditions. Previously, these poor soils were 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 in which it occurs, retard seepage, accelerate the rate at which drainage occurs, increase the stability of slopes, mitigation of liquefaction potential, etc.
Based on the soil conditions, a suitable method of ground improvement should be considered keeping in view of the economic feasibility as well as the time frame. In practice, ground improvement is widely used in a broad construction spectrum from industrial, commercial and housing projects to infrastructure construction for dams, tunnels, ports, roadways and embankments. This paper presents two different ground improvement techniques along with a case history for each of the technique as an example.

II. OBJECTIVE

- 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.

III. METHODS OF GROUND IMPROVEMENT

The methods of ground improvement that can be adopted depend basically on nature of strata and purpose of improvement. The methods available are as follows

A. *For cohesive soils:*

- Vertical Drains.
- Vacuum Dewatering.
- Stone columns.
- In-situ deep mixing.

B. *For cohesionless soils:*

- Compaction piles.
- Vibro compaction.
- Stone-columns.
- Dynamic compaction.
- Compaction by deep blasting.
- Grouting

The final choice among the methods available will depend on overall economy in the total foundation cost. In most of the cases ground treated with one of these methods results in less foundation cost compared to the cost of pile foundation which is to be otherwise adopted if no treatment is adopted.

IV. PREFABRICATED VERTICAL DRAINS

In the past, sand drains consisting of boreholes filled with sand were extensively used for accelerating the settlement. The holes were formed by driving, jetting or auguring. Typical sand drains have diameters ranging from 200 to 450 mm with a spacing of 1.5 to 6 m. The drains may be placed in triangular or rectangular pattern. Currently, geosynthetics band drains in the form of strip (or band) are extensively used. The band drains are of composite construction, a corrugated or studded inner core wrapped in a filter fabric, normally a non-woven geotextile (Fig. 3). The drains are typically about 100 mm wide and 2 to 6 mm thick. The advantages of Prefabricated Vertical Drains (PVD) using geosynthetics are:

- Easy, rapid installation possible.
- Made of uniform material, easily stored and transported.
- Equipment needed is lighter than the rigs used for equivalent sand drains.
- Low cost compared to traditional sand drains.

Manuscript Received January 2014.
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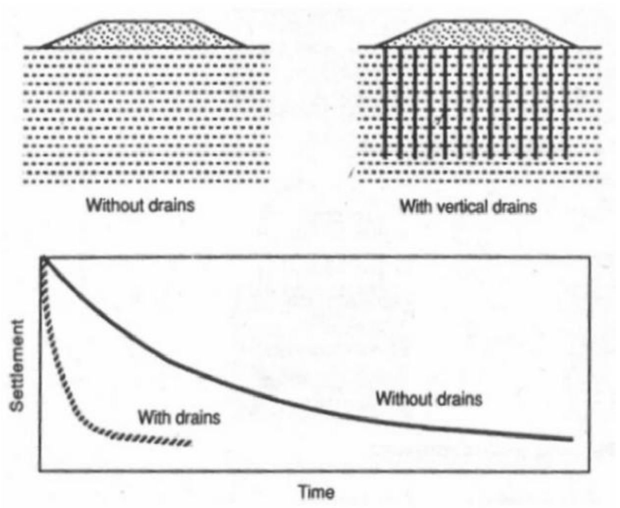

Fig. 1 Beneficial effects of vertical drains (after Hausmann, 1990)

V. STONE COLUMN TECHNIQUES

The use of stone column as a ground improvement technique is of recent origin. The method is generally adopted in a clayey soil. This can be treated as the extension of technique of densification of cohesionless soils by vibroflot. Earlier stone columns were formed by vibroflot but now they are also formed by forming a bore as in bored cast in situ concrete piles.

The primary purpose of soil improvement by stone column techniques is mainly to increase the bearing capacity of foundation soil and also to reduce post construction settlement. The method has been mainly used to improve subsoil below tank foundations and to a limited extent to improve subsoil below buildings, embankments etc.

In recent years, stone columns are also been used in pre bored holes by compacting the granular fill material by a rammer. This method has been developed in India and has been gaining importance in Indian practice. In this method ordinarily bored piling equipment is used. This method is illustrated in Fig. 2

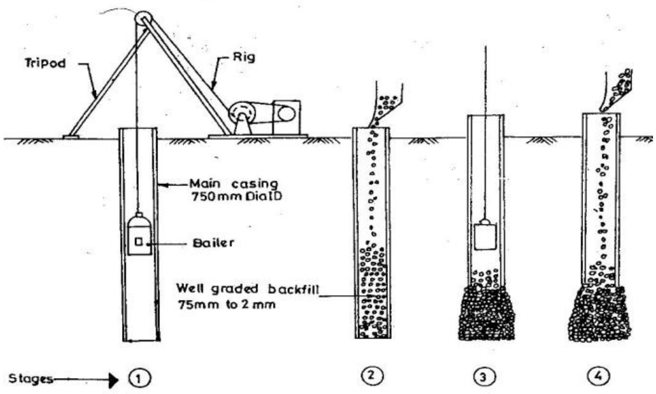

Fig. 2 Formation of stone column using pre bored hole

- **Stage 1:** Boring by bailer with casing to full depth.
- **Stage 2:** Filling the granular fill to thickness 2 to 3 m.
- **Stage 3:** Withdraw the casing partially and ram the backfill to the specified set. Bottom of casing should be at least 0.3 m below the top of rammed fill.
- **Stage 4:** Add additional granular charge and repeat stage 3, till the full length of column to ground level is formed.

VI. PROBLEM FORMULATION

➢ Design of Prefabricated Vertical Drain.

A. Data:

- Vertical Coefficient of Consolidation (C_v) = 0.20*(365*24*60*60)/10000.
- Radial / Horizontal Coefficient of Consolidation (C_r) = (1 to 3)C_v cm^2/sec.
- Effective diameter of flexi drain (d_w)= 0.65m.
- Average degree of consolidation (U)=90% i.e. 0.9.

B. Calculation:

- Required spacing of drain=(depend upon importance of work)
- Influence diameter=1.5 spacing of drain=D
- Dimensionless factor n=D/d_w
- time required for 90% consolidation is $(t=D^2/8C_r[\ln(D/d_w)/1-(1/n)^2]-0.75+0.25*1/n^2*\ln[1/1-U]$.

➢ Design of stone column.

A. Data

- Proposed diameter of stone column.
- Area of individual stone column
- Soil stratification=mixed soil i.e. Sandy silt/ Silty sand.
- Angle of internal friction of soil.
- Cohesion of soil.
- Unit weight of soil.
- Ground water table (20 m below existing ground level).
- Effective unit weight of soil.
- Angle of internal friction of column material.
- Passive pressure coefficient of soil=

$$Kp\ soil = \frac{\{1 + (\sin\pi * \emptyset)/180\}}{\{1 - (\sin\pi * \emptyset)/180\}}$$

  Where, Ø= angle of internal friction of soil.
- Passive pressure coefficient of column material:

$$Kp\ column = \frac{\{1+ (\sin\pi * x)/180\}}{\{1- (\sin\pi * x)/180\}}$$

  Where, x= Angle of internal friction of column material.
- Coefficient of lateral earth pressure, $=K_o = 1- \sin\varphi$.
  Where φ= angle of internal friction
- Average bulge depth, Z=2*D

B. Design calculation:

a) Capacity of individual stone column based on bulging of column (sandy silty soil).

- σrl= Pp= Passive pressure.
- Passive pressure= $(y+Z*Kp_{soil}) + (2*Cu\sqrt{Kp_{soil}}$.
- Limiting axial stress in the column, when it approaches shear failure due to bulging σv is given by $\sigma v= \sigma rl*Kp_{column}$
- Safe load on column due to bulging effect=Q_1= $\frac{\sigma v * area\ of\ column}{factor\ of\ safety}$

b) Capacity based on Surcharge effect:

- the increase in capacity of the column due to surcharge may be

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computed in terms of increase in mean radial stress of the soil as follows:

$$\delta\sigma ro \frac{q_{safe}}{3(1+2K_o)}$$

Where $\delta\sigma ro$= increase in mean radial stress due to surcharge

- increase in ultimate cavity expansion stress=$\delta\sigma ro F q'$
  Where Fq'= vessic dimensional less cylindrical cavity expansion factor (Fq'=1)
- increase in yield stress of the column= $(Kp_{column}-Kp_{soil})*\delta\sigma ro$
- increase in safe load of column Q_2 is given
  $Q_2=\{(Kp_{column}-Kp_{soil})*\delta\sigma ro*Fq'*As\}$/factor of safety

c) Capacity based on Bearing Support provided by intervening soil:

- SBC of soil with FOS
- effective area of stone column including the intervening soil for triangular pattern= $0.866*S^2$
  Where S= spacing of stone column=3D(assume)
- area of intervening soil for each column Ag
  = (effective area of stone column-area of individual stone column)
- safe load taken by the intervening soil Q_3=SBC insitu soil*Ag
- overall safe load on each column and its tributary soil=$Q_1+Q_2+Q_3$
- improved safe bearing capacity =
  $(Q_1+Q_2+Q_3)$/effective area of stone column
- check for punching of pile: Adopt minimum depth of pile below exiting ground level(i.e. upto firm strata)
- Ultimate capacity of individual stone column=Q_1+Q_2*FOS
- Ultimate capacity as a rigid pile=(αCu+KPdiTanδ)As

$$\text{Where } \tan\delta = \tan\pi\frac{\text{angle of internal friction}}{180}$$

$$Pdi = 1*\frac{\text{adopt minimum depth}}{2}$$

d) Settlement analysis:

▪ stress concentration ratio, n =$\sigma s/\sigma g$

Where,

- σs= vertical stress in compacted column=(Q1+Q2)/As
- σg= vertical stress in surrounding ground=SBC of insitu soil
- replacement ratio, as= As/(As+Ag)
- settlement reduction ratio, β=1/[1+(n-1)as]
- settlement of treated ground = settlement of untreated soil * β
- settlement of untreated ground = S = (H/1+e0) *Cc * log10 ((P0+ dP)/P0)

Where,

- e_0=void ratio.
- H= thickness of treated soil.
- Cc=compression index(dimensionless).
- P0=overburden pressure.
- dp= pressure increment

The main objective in the present optimization problem is to optimize R.C.C T-beam girder with deck slab system and also to formulate the problem properly in terms of optimization problem and so as to solve this optimization problem with the help of optimization techniques. Objective function to be satisfied is the cost of R.C.C. T-beam bridge deck whose main components are cost of concrete and steel. It is assumed that cost of steel, launching and casting formwork etc. are directly proportional to volume of concrete, hence all these costs are included in the rate of concrete.

VII. RESULT

- Comparison between PVD and stone column

	PVD	Stone column
Settlement (mm)	730.75	469.59
Rate (Rs/m^3)	870	770.37

VIII. CONCLUSION

- In view of achieving the aim and objectives of this study a detailed literature survey was being carried out. It gave us an idea regarding different methodologies adopted for ground improvement techniques. It was decided to go for the use of the software Microsoft Excel for the calculation of settlement and time period for untreated land.
- By using this software settlement was calculated. A comparative study was carried out between PVD and stone column.
- By extracting result we have concluded that PVD is costlier than stone column. It has also seen that settlement by using PVD is more than stone column.

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