G. PULLAIAH COLLEGE OF ENGINEERING AND TECHNOLOGY
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Nandikotkur Road, Venkayapalli, Kurnool – 518452

Department of Civil Engineering

Bridge Course
On
Ground Improvement Techniques

Need for Engineering ground Improvement

When a project encounters difficult foundation conditions, possible alternate solutions are:

- Avoid the particular site
- Design the planned structure accordingly.
- Use a soft foundation supported by piles, design a very stiff structure which is not damaged by settlements
- Remove and replace unsuitable soils.
- Attempt to modify the existing ground.

Classification of Ground modification Techniques:

There are 4 Groups of Ground Improvement techniques.

Mechanical Modification:

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.

Hydraulic Modification:

- Free pore water is forced out of soil via drains or wells.
- Course grained soils; it is achieved by lowering the ground water level through pumping from boreholes, or trenches.
- In fine grained soils the long term application of external loads (preloading) or electrical forces (electrometric stabilization)

Physical and chemical modification:

Stabilization by physical mixing adhesives with surface layers or columns of soil. Adhesive includes natural soils industrial byproducts or waste. Materials or cementations or other chemicals react with each other and/or the ground.
When adhesives are injected via boreholes under pressure into voids within the ground or between it and a structure the process is called grouting. Soil stabilization by heating and by freezing the ground is considered thermal methods of modifications.

Modification by inclusions and confinement:

Reinforcement by fibers, strips bars meshes and fabrics imparts tensile strength to a constructed soil mass. In-situ reinforcement is achieved by nails and anchors. Stable earth retaining structure can also be formed by confining soil with concrete, Steel, or fabric elements

Suitability, Feasibility and Desirability

The choice of a method of ground improvement for a particular object will depend on the following factors.

- Type and degree of improvement required
- Type of soil , geological structure, seepage conditions
- cost
- Availability of equipment and materials and the quality of work required
- Construction time available
- Possible damage to adjacent structures or pollution of ground water resources
- Durability of material involved (as related to the expected life of structure for a given environmental and stress conditions)
- Toxicity or corrosivity of any chemical additives.
- Reliability of method of analysis and design.
- Feasibility of construction control and performance measurements. If soil is moist, freezing is applicable to all type of soil.

Mechanical Modification

Major aim of compacting soil

- Increases shear strength.
- Reduces compressibility.
- Reduces permeability.
- Reduces liquefaction potential.
- Controls swelling and shrinking.
- Prolongs durability.

Shallow surface compaction

Achieved by static pressure and or dynamic pressure caused by impact or vibration.

Deep compaction Techniques:

Densification of deep soil is achieved by the following techniques.

- **Precompression**: Pre loaded by means of a surcharge on the surface in an array of boreholes, causing a ground to consolidate.
- **Explosion:** Explosives are detonated on the surface in an array of boreholes causing a loose soil structure to collapse.
- **Heavy tamping:** A large mass is dropped in to the ground surface, causing compaction and possibly long term consolidation.
- **Vibration:** Densification is achieved by a vibratory probe or piles.

Explosion:

Explosion of charges on the ground surface or in deep boreholes causes shear stresses in the soil which break

Grouting in civil engineering refers to the injection of pumpable materials into a soil or rock formation to change its physical characteristics. It is one of the ways in which ground water can be controlled during civil engineering works. Grouting is suitable where soil permeability would create a heavy demand on pumping or where ground conditions mean it may be economically inefficient to bore wells. Grout may also be used in the formation of pile foundations, ground anchors, under reaming, underpinning, in road construction, dam construction and so on. Different materials may be used for grouting depending upon the soil or rock type, the area to be grouted and so on. However, the basic process is the same: the soil or rock is injected with fluid grout which sets and reduces or acts as a sealant on the material's permeability. Grouting is relatively costly and so wastage must be controlled. This is achieved by the use of additives which improve the gelling properties of the grout and limit its spread through the ground.

Injection methods

Typically, grouting is carried out is by driving pipes or boring holes into the ground, and then pumping the grout solution at high pressure through inserted tubes. The extent of grouting required for a particular area is determined through investigation of ground conditions and the calculation of a drilling pattern. This considers the size, spacing and depth of the holes required. The type of grout and the particular ground conditions will influence the spacing of the holes. Site conditions will influence the tools used for the boring process, but pneumatic tools, diamond drills or wash-boring are the most common. Alluvial soils are prone to collapse and so holes are usually cased. The pressure of the grout injection is dependent on soil conditions, and in-situ testing may be carried out before the correct pressure is determined. Pressures usually range from 1 N/mm2 for sands to 7 N/mm2 for rock.

Grouting materials

There are several different types of material used for grouting:

Cement grouting

Cement (or cementations grout) is used for grouting materials with a high permeability. Neat cement and water or a mixture of sand (4 parts) to cement (1 part) is the usual composition.

Holes are bored in a radius around the area to be excavated before being injected with a thin grout, the viscosity of which is then increased by reducing the water-cement ratio. If required, secondary holes are bored between the primary holes to ensure the complete grouting of the area.

Bentonite grouting

Bentonite is produced from clay which has thyrotrophic properties, meaning it forms a highly water-resistant gel which, when mixed with additives, can create a permanent barrier to water flow. This is used where soil particles are too small for cement grouting, most commonly to combat seepage in alluvial soils beneath the foundations of dams or other water-bound structures.

Chemical grouting

Chemical grouting is used in soils of medium to coarse grading. Materials such as sodium silicate and calcium chloride are mixed together in liquid form and solidified into a gel. There are two main processes:

- 'Two-shot' process: Pipes are driven into the ground. One chemical is injected followed by another meaning that the reaction, and soil strengthening, is rapid.
- 'One-shot' process: This involves chemical mixing prior to injection, with the hardening being delayed by the composition. This allows for wider borehole spacing.

Chemical grouting has the advantages of allowing economical spacing of bore holes, greater penetration of the grout, and more flexibility in terms of the time of grouting.

Resin grouting

As opposed to chemical grouts, resin grouts have a very low viscosity which is able to penetrate fine sands. The type of resin used depends on the chemical content of the local water table and may result in different times for setting. Common types include:

- Tannin-based grouts.
- Phenol-formaldehyde.
- Resorcinol formaldehyde.

Bituminous grouting

Bitumen emulsion can serve as a suitable grouting material that can be injected into fine sands as an impermeable barrier to water. Soil strength will not be increased, but cut-off walls beneath dams and other water-bound structures can be formed effectively.

Vibro-compaction methods

Compaction at selected locations using vibrations and vibratory equipment results in compaction to large depths. The zone of compaction around a single float is a function of type of float. The success of in situ densification depends on grain size distribution of the in situ soils, and that of backfill soil.

Vibro Replacement

VibroReplacement is a technique of constructing stone columns through fill material and weak soils to improve their load bearing and settlement characteristics. Unlike clean granular soils, fine grained soils (such as clays and silts) do not densify effectively under vibrations. Hence, it is necessary to form stone columns to reinforce and improve fill materials, weak cohesive and mixed soils.

Principle of VibroReplacement

The stone columns and intervening soil form an integrated foundation support system having low compressibility and improved load bearing capacity. In cohesive soils, excess pore water pressure is readily dissipated by the stone columns and for this reason, reduced settlements occur at a faster rate than is normally the case with cohesive soils. Vibro-compaction and Vibro-replacement techniques have been used to a considerable extent in ground improvement Projects .They have been very cost effective in infrastructure projects. Drainage function of the stone columns has been very useful in mitigation of damages due to liquefaction.

Preloading

- Increases the bearing capacity
- Reduces the compressibility of weak ground
- Achieved by placing temporary surcharge on the ground.
- Surcharge generally more than the expected bearing capacity.
- In cohesion less soil and gravel lowering water table
- Most effective soft cohesive ground.

The process may be speed up by vertical sand drains. Vertical 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 soil benefit 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.Pre loading Vertical Reduce total and differential settlement speed up to settlement process. Economy in foundation system does not reduce the amount of deformation under a given load.

Cylindrical Sand Drains

Sand drains consisted simply of boreholes felled with sand. The holes may be formed by driving, jetting and/or angering. Its diameter is 200 to 450mm and would be spaced 1-5 to 6m apart. A large diameter sand, in a fine grained soil, enables rapid consolidation of surrounding material and also provide vertical compressive reinforcement.

Monofilament wovens:-contains single filaments in warp (machine direction) and weft (cross machine) direction.

Multifilament wovens: - made of multifilament yarns in warp and weft direction.

Tape wovens:- Split –film tapes (rather than filaments with circular or elliptical cross section) are used.

Non wovens: - Have essentially random textile structure they are further categorized according to how fibers are interlocked or bonded, which is achieved by mechanical, chemical, thermal means.

Knitted wovens: - Produced by interloping one or more ends of yarn or comparable material.

Types (Examples of Geotextiles):

- Bidim, Foss Geomat , Trevira (non woven-needle –punched polyester)
- Polyfelt sodoca, (non woven, needle-punched polypropylene)
- Typar (non woven, spun-bonded poly propylene)
- Terram 700 (non woven, melded, 33% polyethylene,67% poly propylene.)
- Geolon, Nicolon, polytrac, propex (woven polypropylene)
- Terra firma (woven polyester)
- Terrafix 370Rs, Lotrack 200 (woven –nonwoven composites

Geotextiles and Geomembranes

Fabrics are used to provide containment if they are used to form soil or concrete filled bags, tubes, or mattresses. Fabrics are used to act as a tensioned membrane if it supports loads across a gap or plastic zone of soft soil Fabrics may be required to provide cushioning against localized stresses which may cause puncturing or abrasion If placed on the surface of a slope the Geotextiles may prevent erosion and dispersion of soil due to wind, surface runoff or wave action.

Applications

1. Embankments over very soft soils
2. Unpaved road supports
3. Retaining walls
4. Slope stabilization

Embankments

Embankment can fail in a multitude of ways involving excessive settlement and lateral spreading, with or without single or multiple failure surfaces and surface bulging becoming apparent. Geotextiles provides restraint against lateral deformation and assist in load distribution on the soft subsoil. Stability analysis of a reinforced embankment will have to take the following modes of failure

(a)Block sliding on the Geotextiles:

A vertical crack or other type of failure through the embankment isolates a block of soil which slides outward on geotextiles.A simple analysis would assume horizontal active earth pressures pushing outward and soil fabric friction resisting the process.

(b)Unpaved roads:

- Reinforcing action of Geotextiles can be used in unpaved roads for economic advantages.
- Geotextiles also fulfill additional basic functions such as separation, filtration and drainage.
- Nonwoven and woven fabrics are used in road construction.

- Unpaved roads without fabric
- The fabric provided restraint of the aggregate and the sub grade if placed at their interface.
- Subsidence associated with wheel path rutting can develop tension in a fabric built into road structure. This is the case with high-modulus fabrics with sufficient soil fabric friction to develop an anchorage zone outside the loaded area.

(c)Rail roads:

Geotextiles installed in the track bed are submitted to extreme conditions of cyclic stress and seepage flow. Geotextiles directly contact with coarse ballast without protective layers above and below, are subjected to significant abrasion and puncturing which affects their filtration and reinforcement capacity. Laboratory tests and field observations confirm that heavy nonwovens perform better than lighter nonwovens. Geotextiles are successful in solving difficult track foundation. Economic gains and better long term track performance could be achieved by protective layer above /or below the installed fabric .With particular reference to road and embankment construction proper management of a Geotextiles reinforced soil project requires the following actions.

Site preparation

Level site and remove obstructions such as sharp tree stumps and boulders, minimize disturbance of the sub grade where soil structure, roots in the ground and light vegetation may provide additional bearing strength.

Equipment selection

Use low ground pressure and small dump trucks for initial stage of construction pay attention to ground disturbance caused by turning equipment and dumping procedures.

Fabric placement

Roll rather than drag geotextiles.A into place giving attention to the isotropic properties of the fabric (i.e. warp direction parallel to road alignment). Eliminate wrinkles, tension fabric and provide edge anchorage for increased membrane action in cures, cutting and sewing of or overlapping may be necessary.

Aggregate placement and compaction

Minimum cover is 200 to 300 mm, depending on aggregate size and weight of trucks. Maximum lift thickness may be imposed in order to control the size of the mud wave (bearing failure) a head of dumping due to excessive fill weight compaction of first aggregate layer is achieved by the construction equipment alone.

Properties of Geotextiles

- Physical properties
- Mechanical properties
- Hydraulic properties

- Endurance properties
- Degradation properties

Physical properties of Geo-Grids

Structure

- Intersecting strips
- Woven
- Woven & Knit
- Punched sheet

Polymer

- Polyester
- Polyethylene
- Polypropylene

Chemical Effects

- Biological Effects
- Temperature effect
- Weathering Resistance

Geomembranes

- Geomembranes are impermeable liquid or vapor barriers made from continuous polymeric sheets.
- Made from impregnation of Geotextiles with asphalt or elastomeric sprays.
- Geomembranes are not absolutely impermeable but are relatively impermeable when compared to Geotextiles or soils or even to clay soils.
- Geomembranes are thin sheets of flexible thermo plastic or thermoset polymeric material.

Thermoplastic polymers:

- Polyvinyl chloride
- Polyethylene
- Poly amide (PA)

Thermo set polymers:

- Isoprene-Isobutylene
- Polychloroprene
- Ethylene vinyl acetate

Liquefaction of Soils

Many failures of structures like earth structure, slopes and foundations on saturated sands are due to liquefaction of sands. Example – 1964 earthquake in Niigata Liquefactions appears in the form sand foundations.

Definitions:

Liquefactions: A condition where a soil will undergo continued deformation at a constant low residual stress or with no residual resistance. It is due to the build-up and maintenance of high pore water pressure which reduces the effective confining pressure to a very low value. Pore pressure build up may be due to static or cyclic stress applications.

Initial liquefaction: A condition where during the course of cyclic stress application the residual pore water pressure on completion of any full stress cycle become equal to the applied confining pressure the development of initial liquefaction has no implications concerning the magnitude of the deformations.

Initial liquefaction with limited strain potential, cyclic mobility or cyclic liquefaction: It denotes a condition in which cyclic stress applications develop a condition of initial liquefaction and subsequent cyclic stress applications because limited strain to develop either because of the remaining resistance of the soil to deform.

Soil Nailing

- Soil nails are more or less rigid bars driven into soil or pushed into boreholes which were subsequently filled completely with grout.
- Together with insitu soil, they are intended to form a coherent structural entity supporting on excavation or arresting the movement of on unstable slope.

Size of nails varies from thin steel bars to light concrete piles terms such as micro piles and root piles. Most nailed supported structures must still be closed as temporary, this is due to corrosion.

Analysis of Nailed soil

Methods of analysis proposed soil for nailed soil vary with respect to

- Geometry of failure surface
- Safety factor (in tenors of overturning moment, sheer strength, fraction angle, cohesion, reinforcement properties etc).
- Direction of the tensile stabilizing force provided by the nails.
- Consideration of bending and shear forces in the reinforcement a reaction to development of passive