Review Paper on Different Techniques Used to Prevent Soil Liquefaction

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Abstract- *"Liquefaction" A major cause of structural damage during earthquake. As one the most hazardous event is discussed, certain analysis for soil is to be performed to understand the behaviour of soil and its stability towards such actions on different sites and determining the liquefaction susceptibility. Based on different parameters and liquefaction susceptibility on which soil strength is considered certain Ground Improvement Techniques (GIT) are used for Chandigarh, Kolkata, Orissa, Lucknow, Gandhinagar, Vijayawada, Delhi, Vishakhapatnam, Pushkar, Bhuj and Kutch accordingly. In this, the designing of counter measures for remediation of liquefaction with precautionary measures is being done. The objective is to take one of the Ground Improvement Techniques accordingly to overcome the chances of liquefaction for eachsoil. The important constraints that are to be self-addressed is Economical, sustainable and to be socially acceptable*

Keywords- Soil, Liquefaction, Compaction, Techniques, Pores, Pressure, Density

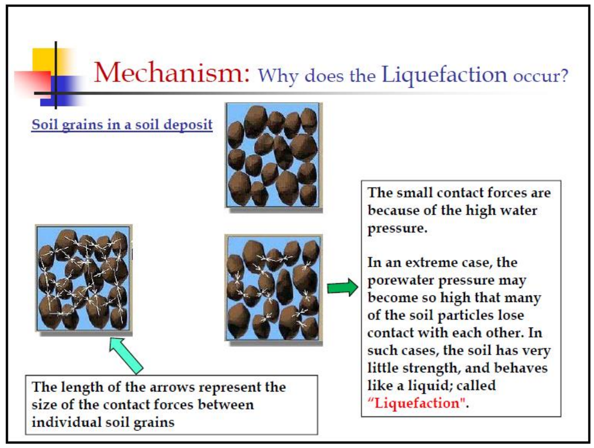
I. INTRODUCTION

- What is Liquefaction?

Liquefaction occurs in saturated soils. All pores are filled with water; Soil is no thirstier!!
The water in the pores exerts the pressure on soil particles called pore pressure that influences how tightly the soil particles are pressed together.

- Why does the Liquefaction occur?

  - -Prior to an earthquake: the pore pressure is low.
  - -Earthquake shaking causes pore pressure to increase undrained condition!!
  - -Pore pressure = overburden press/confining stress effective stress is zero; no shear strength!!
  - -Soil particles start readily move with respect to each other due to zero shear strength. Liquefaction occurs!!



- When has Liquefaction occurred in the past?

1. Alaska Earthquake, USA, 1964
2. Niigata Earthquake, Japan, 1964
3. Loma-Prieta Earthquake, USA, 1989
4. Kobe Earthquake, Japan, 1995
5. Chi-Chi Earthquake, Taiwan, 1999
6. Bhuj Earthquake, India, 2001
7. Many More…!!

REASON FOR SOIL LIQUEFACTION

Due to the forces exerted by gravity, soil particles naturally rest upon each other and, depending on the properties of the soil, form sort of grid that is relatively stable (or can be made so by compaction or other construction practices).

During liquefaction the water pressures become high enough to counteract the gravitational pull on the soil particles and effectively 'float', or suspend, the particles. The soil particles can then move freely with respect to each other.

Since the soil is no longer behaving as an inactive grid of particles, the strength and stiffness of a liquefied soil is significantly decreased, often resulting in a variety of structural failures

In order to have soil liquefaction, you need three things:

1. Granular soils - typically clean (low fine content) sands
2. Water - typically at or near saturation
3. Impulse loads - shock or vibration loading

When these conditions are met simultaneously, liquefaction can occur. Typically, the limiting condition is either water (dry soils don't liquefy) or the impulse loads (from construction equipment vibrations, earthquake, or impacts).

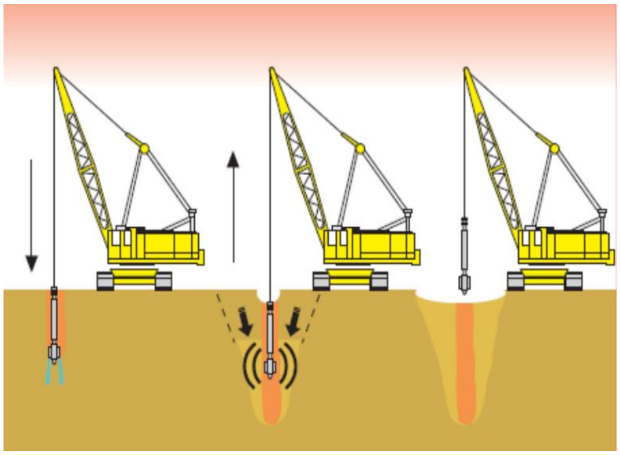
II. GROUND IMPROVEMENT TECHNIQUES (GIT)

1. VIBRO COMPACTION OR VIBRO FLOATATION

Vibro Compaction is an established ground improvement method for stabilising granular soils such as loose sands, gravels, and some hydraulic fills. The technique is primarily used for seismic mitigation and in-situ densification of loose sands up to 30m deep basic technique

A vibroflot is penetrated to the required design depth, assisted by water jetting from the nose cone. Upon reaching design depth water jetting is reduced before the Vibro flot is slowly extracted, with pauses at regular intervals to ensure satisfactory levels of compaction are achieved at each depth

The vibroflot is withdrawn back to the surface where a zone of compacted ground is formed around the insertion point. Additional site won sand may also be added at the top of the hole to fill the cone of depression that is formed. The rate of extraction is varied to suit the conditions encountered onsite and to ensure that the correct amount of densification is achieved for each project.



ADVANTAGES

- When the process is done properly, it will reduce the possibility of differential settlements that will improve the foundation condition of the proposed structure.
- It is the fastest and easiest way to improve soil when bottom layers of soil will not provide good load bearing capacity.
- It is a great technology to improve harbour bottoms.
- On a cost-related standpoint, it helps improve thousands of cubic meters per day. It is faster than piling.
- It can be done around existing structures without damaging them.
- It does not harm the environment.
- It improves the soil strata using its own characteristic.
- No excavations are needed, reducing the hazards, contamination of soils and hauling material out from the site.
- No need to manage table water issues, neither the permits required to manage water discharge and dewatering issues.
- The technique of vibroflotation can be adapted to each scenario and site.
- When vibroflotation is performed at a site, it will reduce the possibility of liquefaction during an earthquake.

LIMITATIONS

Disadvantages associated with aggregate piers can be categorized into two consisting of economic limitations and performance limitations. The requirement of a drilled cavity, and the fact that almost all the soils requiring improvement with aggregate piers, being very soft and compressible, cavity collapse is an inevitable issue. To prevent this, temporary casing is placed, and advanced once the backfilling stage onsets. this slows down the application rate and increases the cost per element. Additionally, where treatment zone depths are required to be greater than say 8 m, aggregate piers shall not be considered as a solution because they give best performance when used in compressible strata as a floating pile to depths up to8m.

APPLICATIONS

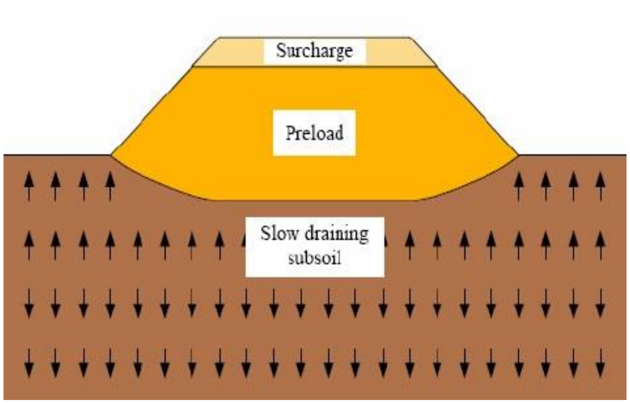
Vibro-flotation was first used in saturated natural fine sands.

Application of vibro compaction are as follows:

- It is applied to improve hydraulic fills
- Vibro-flotation reduces risk of liquefaction during seismic event.
- Vibro-compaction is used over water.
- Depths of 30 m can be treated, and it can be up to about 50 m.
- Multiple vibrators can be coupled together in groups.
- Vibro compaction is used in conjunction with surcharging.

2. PRELOADING OF SOIL

A system of prefabricated vertical drains (PVDs) combined with vacuum preloading is an effective method for accelerating soil consolidation. One common method for improving soft soil is to reduce the water content of the soil through consolidation. For consolidation to occur there must be an increase in effective stress. This can be achieved by increasing the total stress or reducing the pore-water pressure. The former is the so-called fill surcharge preloading method. The latter can be achieved through vacuum preloading. When a surcharge pressure is applied, the increase in the effective stress is dependent on the dissipation of excess pore-water pressures generated as a response to the application of this surcharge. To accelerate the dissipation of pore-water pressure, prefabricated vertical drains (PVDs) are normally used. PVDs are also used together with the vacuum preloading method to distribute vacuum pressure and facilitate the dissipation of pore water. Therefore, PVD techniques become part of the core technologies in the fill surcharge or vacuum preloading methods. PVDs have been used successfully in many soils improvement and land reclamation projects in the world.



ADVANTAGES

- Particularly for the soils having heterogeneous characteristics the reduction in the post construction settlement is achieved.
- For the general grading of the site the pre-load fills are usually used. They usually reduce the considerable cost of the preloading process; it is important because usually preloading processes are quite expensive.
- One of the best merits of this technique is that it is almost free of noise and vibration problems that are faced in other technique. Therefore, it is preferable in those places where environmental restrictions are involved.

DISADVANTAGES

- There could be an unexpected cost increment.
- Further improvement in the project requires the consideration of the preloading programme.
- There may be a unexpected time delay.

APPLICATIONS

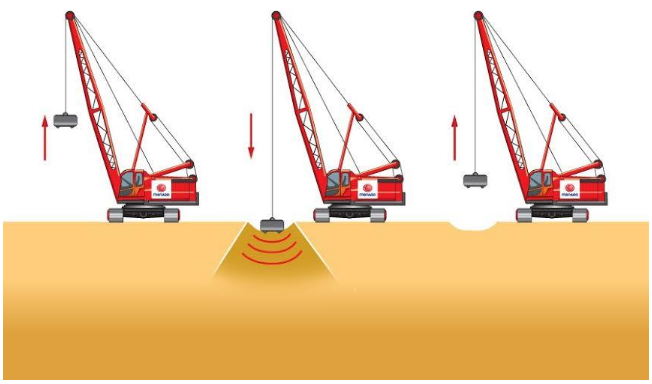
- Reduce post-construction
- Settlement
- Reduce secondary compression.
- Densification
- Improve bearing capacity

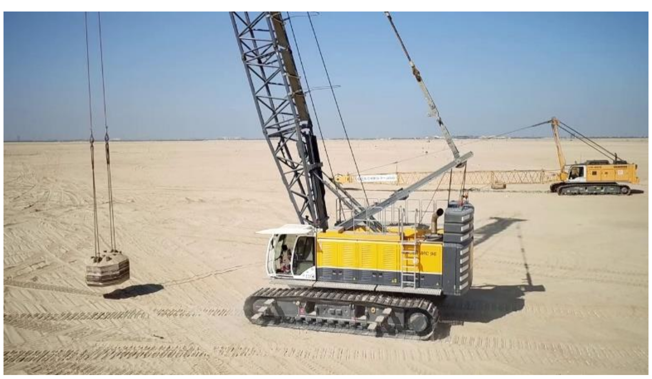
3. DYNAMIC COMPACTION

- Dynamic compaction is a ground improvement technique that densifies soils and fills by using a drop weight.
- The drop weight, typically hardened steel plates, are lifted by a crane and repeatedly dropped on the ground surface.

- The drop locations are typically located on a grid pattern, the spacing of which is determined by the subsurface conditions and foundation loading and geometry.
- Treated granular soils and fills have increased density, friction angle and stiffness.
- The technique has been used to increase bearing capacity and decrease settlement and liquefaction potential for planned structures.
- Dynamic compaction has also been used to compact landfills prior to construction of a parking lots, roadways, and to stabilise large area of embankment works.
- One of the most important considerations regarding the applicability of dynamic compaction is the type of soil being densified.
- Granular materials enable excess pore water pressures that develop during the densification process to dissipate rapidly.

In general, dynamic compaction is most beneficial on a category of soil known as granular materials. Dynamic compaction will be effective in silts, clayey silts and sandy silts.





ADVANTAGES

The main advantage of dynamic consolidation is the *simplicity* of the technique which does not need any advanced equipment, or skill on the part of the operators. The very process is a probing and correcting tool; it provides the geotechnical engineer with *immediate* feedback on ground response. It can be applied over a *wide range of deposits* covering large boulders, broken concrete blocks, silty and clayey materials, building rubble debris and even decomposed sanitary landfills. Since it produces *more uniform compressibility*, it *minimizes differential settlements*. The work can be undertaken during rainy weather. It can be applied to pervious and semi-pervious deposits below water table. On the *cost* side, it is significantly less expensive than other ground improvement methods.

DISADVANTAGES

- Ground vibrations induced by dynamic compaction can travel significant distances from the point of impact, thus limiting the use of dynamic compaction to light weight tampers and low drop heights in urban environments.
- The groundwater table should be more than 6.5 feet below the existing ground surface to prevent softening of the surface soils and to limit the potential of the tamper sticking in the soft ground.
- A working platform may be required above very loose deposits. The working platform also functions to reduce the penetration of the tamper. The cost of the working platform can add significant costs to the project.
- Large lateral displacements (1 to 3 inches) have been measured at distances of 20 feet from the point of impact by tampers weighing 33 to 66 kips. Any buried structures or utilities within this zone of influence could be damaged or displaced.

APPLICATIONS

A percentage of *in situ* density and then correlate density to CPT cone resistance. However, this is quite meaningless as CPT results can be interpreted on their own and without the need of introducing density into the testing methodology.

Although sometimes erroneously specified in projects, implementation of relative density is also a poor choice and there is overwhelming evidence that this parameter must not be used as acceptance criteria of ground improvement projects. Hamidi *et al*. (2011d, accepted, in review) have reviewed the problems associated with the concept of relative density and relative density correlations. In extreme cases, application of relative density can be as accurate as making a wild guess.

The above discussions have been recognised by many geotechnical engineers, and thus a trend has been realised whereas minimum values for practical, efficient and economical field tests such as SPT, CPT or PMT (Menard Pressure meter Test) have been stipulated as acceptance criteria. This, itself, is a positive step forward as it recognises that establishing acceptance criteria based on direct measurement of parameters is more rational and beneficial than making purposeless correlations; however, it is not enough. What lies behind these types of acceptance criteria are calculations that have been carried out by geotechnical engineers to ensure certain design requirements such as bearing capacity, total and differential settlements, liquefaction mitigation or long-term consolidation have been satisfied. However, the condition in which all test values of the soil layers just reach the minimum value is only one of countless possibilities that may satisfy the design criteria, and statistically speaking, the least probable of them all. Furthermore, in techniques with inclusions such as dynamic replacement, stone columns, jet grouting, deep soil mixing and controlled modulus columns, where loads are distributed between the in-situ soil and the inclusions by arching (Hamidi *et al*., 2009b) the minimum value concept becomes blurred as the in-situ soil parameters improve negligibly compared to the much higher inclusion parameters.

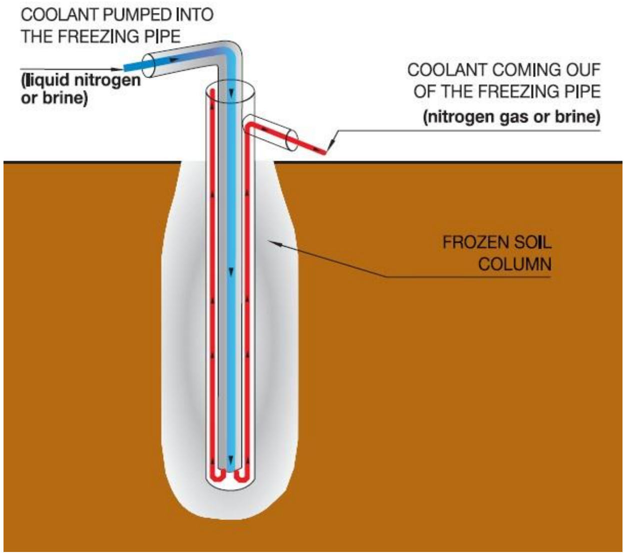
4. GROUND FREEZING

Ground freezing is a soil stabilization technique carried out by continuously refrigerating the soil. Methods, applications and advantages of ground freezing is discussed. Ground freezing is a process of converting pore water or pores into ice by continuously refrigerating the soil.

This method can be use in any type of soil, regardless of size, shape or depth of excavation, soil, or rock formation regardless of structure, grain size or permeability. However, it is best suited for soft ground rather than rock conditions.

It is applicable to a wide range of soils, but it takes considerable time to establish a substantial ice wall and the freeze must be maintained by continued refrigeration as long as required.

The method of artificial ground freezing was found out by German scientist F. Hermann Poetsch, in 1883. It was first used in America in Chapin Mine Company in Iron Mountain, where freezing was performed to a depth of 100 feet.



PRINCIPLES OF GROUND FREEZING

The major principle of this method is to convert the water into ice by external freezing methods to create a water seal and strengthen the soil. The effectiveness of freezing depends on the presence of water to create ice, cementing the particles and increasing the strength of the ground to the equivalent of soft or medium rock.

CONDITIONS WHERE GROUND FREEZING IS MOST EFFECTIVE

- Ground where penetrability by drilling, jet grouting, clamshell excavation, or other vertical cut-off tools is limited.
- Filled ground and ground containing man-made obstructions.
- Virgin ground containing cobbles, boulders, or an irregular soil/rock interface.
- Ground that has been disturbed due to unstable conditions or water inflow.

ADVANTAGES

- Temporary underpinning of adjacent structure and support during permanent underpinning.
- Shaft sinking through water-bearing ground.
- Shaft construction totally within non-cohesive saturated ground.
- Tunnelling through a full face of granular soil.
- Tunnelling through mixed ground.
- Soil stabilization.

DISADVANTAGES

- Very expensive.
- Needs continuously monitoring.
- Volume expansion of water during freezing, leading to soil heave and thaw settlement.

APPLICATIONS

- Sinking and lining of deep mineshafts up to depth of more than 600m
- Deep excavations (shafts)
- Tunnelling using the sequential excavation method

SEM under the protection of a structural and watertight frozen soil body

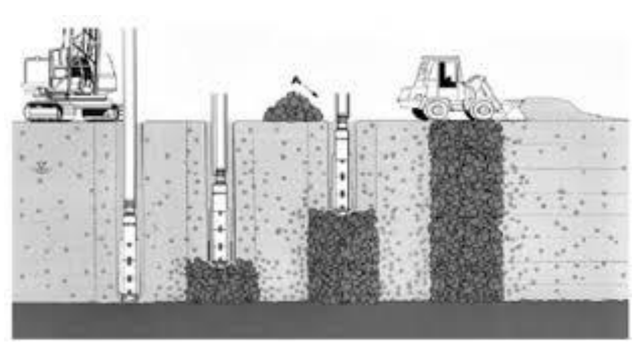
- Cross-passages between shafts and tunnel tubes or between tunnel tubes, respectively
- Large open excavations, retaining walls
- Temporary soil improvement under foundations
- Temporary sealing of leakages
- Temporary water cut-off for connections at the interface between existing and new underground structures

5. **STONE COLUMNS**

Stone Columns are designed to improve the load bearing capacity of insitu soils and fills and to reduce differential settlementsof non-homogeneous and compressible soils, allowing the use of shallow footings and thinner base slabs.

Stone Columns are formed by inserting a vibrating probe to incorporate granular aggregate into the ground via the resulting void. This is followed by the re-compaction of granular aggregate. Both Top and Bottom feed techniques are available, depending on the stability of the insitu soils and water level. The Stone Columns are typically installed under uniformly loaded structures, such a building slabs and embankments, on a regular grid spacing. A load transfer platform can then be designed to spread the load from the structure to the improved ground

This technology is well suited for the improvement of soft soils such as silty sand, silts, clays and non-homogeneous fills. Due to their lack of lateral confinement organic soils, peat and very soft clays are not suitable for this method, and other ground improvement methods need to be considered. “Liquefaction” A major cause of structural damage during earthquake. As one the most hazardous event is discussed, certain analysis for soil are to be performed to understand the behaviour of soil and its stability towards such actions on different sites and determining the liquefaction susceptibility. Based on different parameters and liquefaction susceptibility on which soil strength is considered certain Ground Improvement Techniques (GIT) are used for Chandigarh, Kolkata, Orissa, Lucknow, Gandhinagar, Vijayawada, Delhi, Vishakhapatnam, Pushkar, Bhuj and Kutch accordingly. In this, the designing of counter measures for remediation of liquefaction with precautionary measures is being done. The objective is to take one of the Ground Improvement Techniques accordingly to overcome the chances of liquefaction for eachsoil. The important constraints that are to be self-addressed is Economical, sustainable and to be socially acceptable.



METHODS

- Stone columns are formed by inserting a 130kW hydraulic or electric vibroflot using air as a jetting fluid, equipped with a pressure chamber facility. This combination gives the best results for the incorporation of the granular column backfill to the bottom of the column and delivers the continuity and optimum compaction required. The vibrating probe penetrates the soil to the design depth or refusal, and as a result the soil is displaced laterally without producing any spoil.
- As the probe is lifted the granular fill is deposited into the void by gravity and assisted by the injection of compressed air. The aggregate is then compacted by repeated re-insertion of the vibrating probe, in lifts of 30-50cm, until the aggregates reach the surface.

The final diameter of the Stone Column depends on the properties of the surrounding soils and may vary with depth in non-homogeneous soils.

ADVANTAGES

1. Reduce total and differential settlement.
2. Increase the bearing capacity of a site to make it possible to use shallow foundation on that soil hence, saving lot of money and time.
3. Accelerates the rate of consolidation in cohesive soil by providing drainage to wate
    - To reduction of total and differential settlements.
    - To reduction of liquefaction potential of cohesionless soil.
    - To increase the bearing capacity of a site to make it possible to use shallow foundation on the soil.
    - To increase the stiffness.
    - To improve the drainage conditions and environment control.
    - To control the deformation and accelerate consolidation.

LIMITATIONS

Stone column, when used in sensitive clays, stone columns have certain limitations. There is increase in the settlement of the bed because of the absence of the lateral restraint. The clay particles get clogged around the stone column thereby reducing radial drainage. To overcome these limitations, and to improve the efficiency of the stone columns with respect to the strength and the compressibility, stone columns are encased (reinforced) using geogrids/geocomposites. Deshpande & Vyas (1996) have brought out conceptual performance of stone columns encased in geosynthetic material. Katti et al (1993), proposed a theory for improvement of soft ground using stone columns with geosynthetic encasing based on the particulate concept. (Malarvizhi, 2004).

APPLICATIONS

- TANK FOUNDATION.
- FOOTING (RAFT/ISOLATED).
- REINFORCED EARTH WALLS.
- RAILWAY EMABNKMENT.
- HIGHWAY EMBANKMENT.
- PORTS.

III. CONCLUSION

The aim of this project is to provide knowledge on soil liquefaction, which is a major problem in Civil engineering particularly under the branch of Geotechnical that studies the behavior of soils under the influence of loading forces and soil-water interactions. For this purpose, the various criteria used for evaluating soil susceptible to liquefaction, ground failures resulting from soil liquefaction, factors affecting liquefaction and the in-situ testing procedures used to evaluate liquefaction of soils were studied.

It can clearly be concluded that the ill effects caused by liquefaction have devastating damages to structures built on liquefied soils. Hence the various methods in which the severity of damage as a result of liquefaction can be reduced were also studied, these include the most obvious which is to avoid planning development on liquefaction susceptible soils, building liquefaction restraint structures and improving soils prone to liquefaction by various ground improvement techniques that increase soil drainage and density.

For dispersive soils, the various laboratory test carried to detect these soils were studied and it can be concluded that when dispersive clays are detected in a site investigation and verified by testing, a decision can be made to look for alternate materials or proceed but with necessary engineering provisions to deal with the dispersive properties including soil improvement of the dispersive clay, by adding hydrated lime or non-dispersive clay.

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