BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul LVI (LX), Fasc. 3, 2010
Secţia
CONSTRUCŢII. ĂRHITECTURĂ

ASSPECTS CONCERNING THE IMPROVEMENT OF SOILS AGAINST LIQUEFACTION

BY

COSTEL PLEŞCAN and ANCUŢA ROTARU

Abstract. The specialized literature concerning the Geotechnical Engineering Field indicates the problems due to soil liquefaction and the aggravating consequences that liquefaction phenomenon may cause to buildings.

Some procedures of foundation soil improvement for both existing and future foundations are presented.

The paper also presents three soil remediation methods involving a low level of vibration generated in the process of foundation soil improvement and two case studies representing the usual method in Romania.

Key words: liquefaction; improving methods; compacting grouting; permeation grouting; jet grouting.

1. Introduction

Liquefaction and soil deformation risk mitigation are based on the following improvement methods: densification, solidification, drainage, dewatering and consolidation.

Densification is a standard procedure for liquefaction reparation consisting in soil porosity mitigation, which reduces the volume deformation potential that cause liquefaction. Deformation resistance caused by shear forces increases with density.

Solidification as viable measure of soil remediation against liquefaction is also considered. Solidification prevents soils subsidence and gives it a high cohesive force.

Drainage method tests show that the layers' drainage can accelerate interstitial water pressure dissipation limiting the loss of cohesion and reducing pressures on underground construction.

Declining groundwater by dewatering reduces the degree of saturation preventing the formation of the interstitial water pressure in excess that could cause liquefaction.

The most available techniques applied for soil liquefaction correction are: vibro-compaction, dynamic compaction and sand sealing. These techniques improve the soil mainly by densification and are usually less expensive than other techniques. However, they can cause unwanted vibration levels during work performance.

The soil improvement techniques are effective for each of the allowed or required disturbance of existing structures.

Compaction grouting (compacting by injection) represents a densification technique of liquefied soil that involves a low level of vibration.

The following methods, which imply a low level of vibration, are useful to improve liquefiable ground by solidification:

a) compacting grouting;

b) permeation grouting;

c) jet grouting.

Jet grouting and *in situ* soil mixing are high-cost methods when are used for consolidation or for earth dams. Dewatering is not an alternative because the construction of earth dams, wells of dewatering and maintenance of pumps are more expensive than other methods.

2. Compaction Grouting

Compaction grouting is a soil injection with low workability cement paste that remains homogeneous without entering in the soil pores. The cement mass extends, soil is moved and finally compacted (Fig. 1).

The liquefaction improvement using compaction grouting divides into the following categories:

a) treatment under existing structures;

b) treatment in urban areas with low levels of vibration and noise;

c) treatment in narrow areas.

The execution of compaction by injection technology using bottom-up method takes place as follows.

In the first stage, injection pipes set up on the foundation soil of the existing or future foundations using drilling machines. The injection process begins. Mixture injected through the pipes pushes the surrounding soil; then the injection pipes raises about 0.3…1.5 m and the process renews.

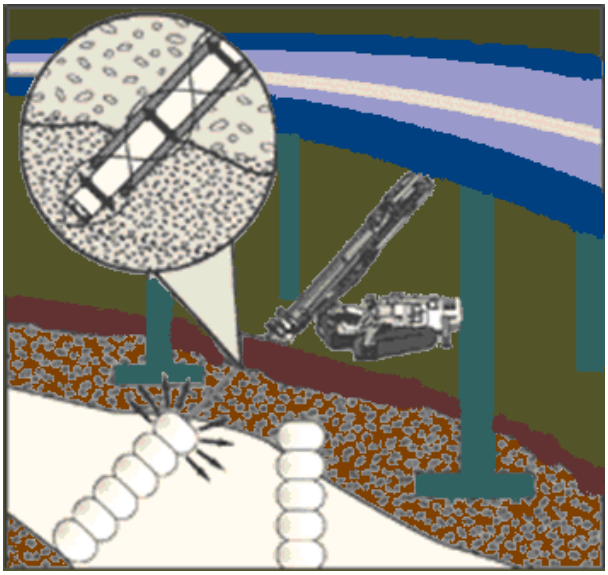

Fig. 1 – Injections [6].

The "in steps" injection process continues until the whole thickness of the soil layer is treated. Injection stabilizes soil layer by density and pressure increasing. The injection process is used when a controlled lifting of the soil surface or existing structures affected by local settlements are necessary.

3. Permeation Grouting

Permeation grouting consists of the injection of a low-viscosity fluid in the soil pores without changes in the soil physical structure. The main goal of permeation grouting is both to strengthen soils through particle cementation (to stabilize the links between particles) and to waterproof ground by filling its pores with injected fluid.

This method improves the soil physical and mechanical characteristics, successfully stabilizes the excavation walls in soft soils, controls the groundwater migration in order to implement the underpinnings at the existing foundations and prevents the effects of earthquakes – compaction and soil liquefaction.

Permeation grouting is a technology used to mitigate liquefaction that is suitable for uncompacted soils solidification in order to reduce the risks of compaction and liquefaction that may occur as result of possible earthquakes.

4. Jet Grouting

Applications of the jet grouting system fall into three broad categories: underpinning or excavation support, stabilization of soft or liquefiable soils [4],

groundwater or pollution control [2].

The method consists of soil injection of a mixed fluid at high pressure forming jets that erode and replace the existing soil with the injection mixture [1]. In general this method begins by drilling small-diameter holes (90…150 mm) up to the final injection depth. Cement mixture is injected into the soil with a metal rod that runs a rotational and withdrawal motion whilst (Fig. 2).

This technology is useful to underpinnings of existing foundations, to support excavations in cohesiveless soils, to control the groundwater migration and to improve the strength of liquefiable soil [3].

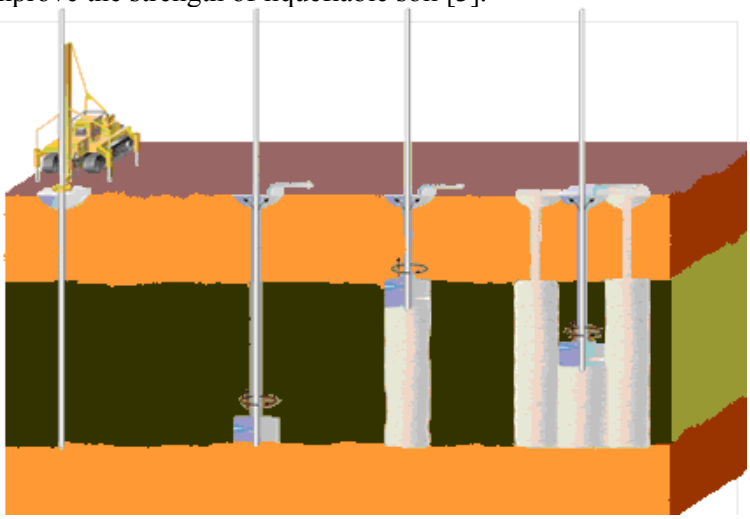

Fig. 2 – Jet grouting method.

4.1. Two Case Studies

a) *First case study*

Fig. 3 – Jet grouting at Lascar Hotel, Bucharest, Romania [7].

The jet grouting method was used at Lascar Hotel in Bucharest, Romania. The project included an underpinning using this method and achieving an excavated site. The foundation soil includes high consistency clay up to 3.80 m depth and sandy silt below it (Fig. 3).

About 160 columns with an average depth of 6 m occupying an area of 800 m^2 have been executed using this method. The execution has been done during December 2008…January 2009 (Fig. 4).

Fig.4 – Execution of pilots using the jet grouting method.

b) *Second case study*

This method is applied for the improvement of civil engineering foundation soils with basement below the groundwater level [8].

The objective is at the crossing of Victoria Road to Frumoasa Street, Bucharest, Romania. The purpose was to obtain a sealed chamber within the existing one using columns injected with cement suspension [6] (Fig. 5).

The execution of the composite walls was carried out in several stages, as follows:

a) jet grouting works have been executed along the perimeter of the existing raft foundations using drilling cores with 250 mm diameter;

b) column positions and their tolerances have been achieved using PVC pipes, through which jet-grouting columns have been executed;

c) at this stage a monitoring program was carried out using driftmeters and piezometers;

d) next step encompassed the enclosure's excavation up to 5.70 m depth.

Fig.5 – Columns realized using the jet grouting method.

5. Conclusions

In Romania, current norms do not include these new improvement methods for the foundation soils; they only briefly remind jet grouting process and present the procedures employed running this new method [5].

The modern methods analysed above used for the improvement of the foundation soil have the advantage of not inducing ground vibrations that would disturb the stability of soil mass and especially of soils with liquefaction potential.

Advantages of the jet grounting system are: availability for nearly all soil types, *in situ* workability, designable strength and permeability, no harmful vibrations, implementation in limited working spaces, free maintenance, reliability, rapidity, the most effective method of underpinning constructions and ability to work under buried active utilities. A major disadvantage of these methods is that they are costly in economic terms.

Received, March 14, 2010

"Gheorghe Asachi" Technical University of Iaşi,
Department of Transportation Infrastructure and Foundations.
e-mail: plescancostel@tuiasi.ro

R E F E R E N C E S

1. Chernyakov A.V., *Evaluation of Dynamic Loads on Underground Structures During Horizontal Jet Grouting of a Saturated Soil*. Soil Mech. a. Found. Engng., **46**, *3*, Springer, New York (2009).
2. Ganeshan V., Yang J.Y., *Jet Grouting and its Applications.* ISGI09 Techn. Session, December 9, 2009, Singapore.
3. Sun X.L., Wang H.Z., *3D FEM Analysis of Horizontal Jet Grouting Prelining in a Tunnel under Asymmetric Loads.* Tunnel. a. Underground Space Technol., **21**, *3-4* (2006); Proc. of the ITA-AITES 2006 World Tunnel Congress and 32nd ITA General Assembly, 366-367.
4. Yang J.G., Xie Y., Wang Y.Z., Ma W., *Pre-Supporting with Horizontal Piles of Jet Grouting in Weak Loess Tunnel.* Internat. Conf. on Inform. Manag., Innov. Manag. a. Ind. Engng., December 26-27, 2009, Xian, China.
5. * * * *Execution of Special Geotechnical Works. Jet Grouting*. SR EN 12716.
6. www.boartlongyear.com.
7. www.kellergeotehnica.ro.
8. www.zublin.ro.

ASPECTE PRIVIND ÎMBUNĂTĂȚIREA PĂMÂNTURILOR LA LICHEFIERE

(Rezumat)

Sunt bine cunoscute din literatura de specialitate şi din practica inginerească problemele cauzate de procesul de lichefiere a pământurilor, cu consecințe agravante asupra construcțiilor.

Se prezintă succinct procedurile de îmbunătățire a terenului de fundare, atât în cazul fundațiilor existente cât şi a fundațiilor ce urmează a se realiza, prin procedee clasice şi prin procedee noi.

Se propun trei metode de remediere a pământurilor care implică un nivel scăzut de vibrații, ce pot fi generate în timpul proceselor de îmbunătățire a terenului de fundare. Sunt prezentate de asemenea două studii de caz pentru cea mai folosită metodă în România.