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ENVIRONMENTAL FACTORS AND LOCAL SOIL CONDITION INFLUENCE RELATED TO SUSCEPTIBLE SOIL LIQUEFACTION IN SEISMIC RISK ASSESSMENT

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Abstract

The present paper consists in the presentation of some important outlines regarding the non-cohesive soils behavior founded in dense state and also the liquefied cohesive soils (loess, silts) under the dynamic loads in terms of critical state model, which offers worth all the possible correlations with their response to static requirements monotone ascending.

The paper presents the liquefaction process occurred in our country to strong seismic motions related to the areas characterized by low mechanical strengths and high underground water level.

The liquefaction process is caused not only by seismic motions, observing the large diversity of cyclical loads, leading to different responses of soil massifs, is possible or not the outlining of their nonlinear behavior in a linear elastic model. The load duration has an important influence on residual deformations, and hence to the qualitative and quantitative aspects of soil behavior.

In order to characterize the dynamic behavior of soil liquefaction is necessary to know the condition of deformability parameters (stiffness) and their resistance, and the manner of cyclic loads variation can influence parameters value. Dynamic soil characteristics are required to seismic design of civil and industrial buildings, especially on important buildings category.

The analysis of factors which determine the soil liquefaction susceptibility depend on the local site conditions, the foundation conditions on construction sites regardless of important buildings category and also on the particular environmental conditions in the unstable areas affected by seismic risk.

Dynamic loads that can cause soil cyclical can be classified into: natural (earthquake, waves) and artificial ones (blast, projectile impact, traffic, construction activities, machinery and equipment with unbalanced mass or cause shocks).

Keywords: seismic, risk, liquefaction, resistance, deformability, cyclic

1. INTRODUCTION

Evaluating the seismic behavior of a saturated soil, from sand to clay, requires addressing the potential for significant strains or strength loss that can contribute to ground deformations or instability during or following the occurrence of an earthquake.

The term "liquefaction" has taken on different meanings in the literature, and it is therefore important to start by defining it and other key terms used in this report. The terms "sand-like" and "clay-like" are used in this report to describe fine-grained soils whose stress-strain behavior during monotonic and cyclic undrained shear loading is fundamentally similar to that of sands and clays, respectively. The term "liquefaction" is used to describe the onset of high excess pore water pressures and large shear strains during undrained cyclic loading of sand-like soils, while the term "cyclic failure" is used to describe the corresponding behavior of clay-like soils [4].

The first attempt to define the conditions under which is generated the liquefaction phenomenon is assigned to A. Casagrande (1936), which introduced the concept of critical pores index. It was found that the shearing deformations are accompanied by a trend of expansion in dense sands and densification in the loose sands. In terms of undrained loads application, water pores pressure is opposed to these volume variations, showing decreases, and the corresponding increase of pressure. A sand that is characterized by an initial pores index, which does not appear variations in volume during drained shearing, so no changes of pore water pressure during the shearing in undrained conditions. Consequently, it was considered that only the sands with a superior state of loose of critical pores index will manifest trends of liquefaction.

Thus, liquefaction potential assessment related to supplementary risk elements represents a necessity in order to reach reliable and feasible solutions to improve the foundation soil characteristics prior to execution stage of constructions [10].

Robertson et al. (1994) suggests a complete classification system for defining the phenomenon of liquefaction, which are recognized in various mechanisms that are involved in the instability of land: (1) The term "flow liquefaction is used for the flow of saturated soils, the contract where dislocation is produced by static or cyclic loads; (2) The term "cyclic softening" to describe the large deformations that occur during shear cyclic pore water pressure due to the increase in land dilatation. This includes "cyclic liquefaction" and "cyclic mobility" [2].

Eurocode 8 "Design of structures for earthquake resistance" contains in Chapter 4 prescriptions for site selection and soil foundation, "Soil potentially liquefiable", translated in Romanian, the term liquefaction is defined as "reducing resistance to shear and / or rigidity due to growth during seismic motion, of interstitial water pressure saturated loose materials likely to produce permanent strains significant, even quasi-normal effort effectively annul field.

2. SOIL LIQUEFACTION PHENOMENA PRODUCED AT STRONG SEISMIC MOVEMENTS

Sands liquefaction phenomena occurred in our country during the earthquake of 1977, caused damage buildings in both rural and urban areas. Vrancea earthquake of 1977 take everybody by surprise because of motion characteristics recorded in Bucharest (a combined effect of the source and the ground conditions) and has illustrated the negative effect of resonance between the vibration period of the ground and buildings (ranging: 1.4s ÷ 1.6 s). The earthquake of 1977, in our country occurred sands liquefaction phenomena generally at small scale (Figure 1), especially around flowing waters in agricultural enceintes, fish farms, such as: Dambovita floodplain, Bragadiru, on the river saw Teleorman, Dambovita River and the confluence of the Arges River, Adancata on Ialomita river, Faurei on Buzau river and some slopes or even higher areas as in Iasi, in the Tatarasi Hill area. [11].

Figure 1. The impacts of liquefaction - Earthquake of March 4, 1977: Bucharest (left) and Buzau (right) Photo © Romanian Earthquake of March 4, 1977, Monograph, 1982

Sand liquefaction produces a decrease of ground bearing capacity, cracking its structure and deployment, can lead to stability loss [12]. Known cases exist when such phenomena caused by earthquakes had a large impact, causing serious damage to buildings situated in such areas (Niigata earthquake in Japan in 1964, Kobe earthquake in Japan, 1995, etc.).

Niigata earthquake of 1964 shocked by the extent of liquefaction phenomena (Figure 2) and the effects of liquefaction on structures and again drawn attention to the importance of local ground conditions [13].

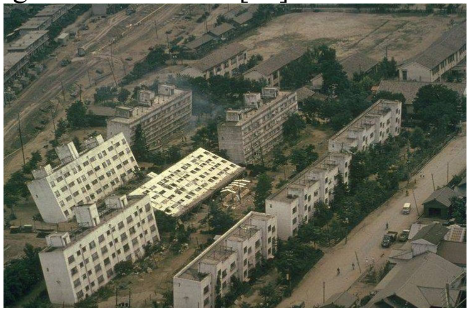

Figure 2. The effects of liquefaction, Niigata City area (©www.ce.washington.edu/~liquefaction/ html/quakes/niigata/niigata.html)

The Kobe earthquake of 1995 was a sad confirmation of the important effects of local ground conditions. Surface geology favored amplification effects induced of ground vibration phenomena such as liquefaction

(Figure 3) and ground collapse [14]. On this occasion seismic records of great importance were obtained aiming a better understanding to the effects of local ground conditions and of the structures behavior.

Figure 3. The effects of liquefaction in Kobe city area (©www.seismo.unr.edu/ftp/pub/louie/class/100/effects-kobe.html)

Loma Prieta earthquake 1989, California caused extensive damage to San Francisco Bay area, especially in the Marina district (situated 100 km from the epicenter). Because these areas are located on swampy deposits, the importance of local geological conditions in seismic risk assessment is reconfirmed [15]. The maximum acceleration of ground in areas with soft deposits are about 0.25 g, while in areas with strong deposits are about 0.1g. The impacts of liquefaction occurred in Loma Prieta earthquake is shown in Figure 4.

Figure 4. The Loma Prieta earthquake liquefaction effects (©http://www.vibrationdata.com/earthquakes/lomaprieta.htm)

Kocaeli earthquake, Turkey affected the county of northwestern Turkey on 17 August 1999. Earthquake was a rupture of the earth crust (slip) along the North Anatolian fault system. The total rupture of the fault was of 110 km. Earthquake surface rupture has been done in sedimentary basins with Pliocene and Quaternary deposits. Kocaeli earthquake effects were represented by liquefaction (Figure 5), surface breaks, fillings densification.

Figure 5. The effects of liquefaction in Kocaeli earthquake, 1999 (©http://www.koeri.boun.edu.tr/depremmuh/eqspecials/kocaeli/kocaeli_eq.htm)

3. LOADS THAT CAUSES THE STABILITY LOSS OF THE LIQUEFYING SOILS

3.1. Static loads

Static requirements are the result of efforts status change in the of the considered soil massive, due to relatively slow variations of external actions or changes in the geometry of the massif. The result of these requests can be the generation of local displacements, which may lead to whole massifs liquefaction [9].

In some cases, liquefaction is determined by a large scale sliding, which by itself would be enough for producing catastrophic effects. This is the case of land collapse during the construction of Fort Peck Dam.

After performing of the technical expertise, it was concluded that the land seizure during the construction of Fort Peck Dam in 1938 was caused by its location in the Missouri river bed, consisting of 49 m of alluvial deposits, which ranged from sands, gravels up to clays.

Under the alluvial dump package, there is a thick alluvial layer of 350 m of shale clay, which contained thin lenses of bentonite, characterized by a high water absorption capacity. The yielding point of the dam appears to be the bentonite lens. In terms of pore water pressure has been found that its value increased during the execution of the dam, without possibility of reduction due to low permeability of shale clay or even of waterproofing. All of this results in decreased shear resistance in the bentonite lens [6].

In some cases, deformation occurs after geometry changing of the deposit, possible for example, as sandbanks formed in areas of river meanders. Classic examples of such flow phenomena who trailed each of one million cubic meters of fine sand on the coast of the Netherlands or in the bed of the Mississippi River; in all cases the balanced tilting of the surface reached eventually to about 3^0.

A particular case was that of the Aberfan slag (United Kingdom, 1966), which suddenly turned into a torrent of mud. In the first time, the cause, determined by a relatively rainy period, was water leakage through heavy cracked clay from the foundation soil and the emergence of considerable pressure in the pore water in the dumps base. A slip, affecting the natural slope from the foundation structure, has generated liquefaction of coarse material in the state loose from the dumps and reactivation of a water spring previously covered by the landfill.

Local instability phenomena, although having as immediate effects - minor degradations, can cause a massive failure by liquefaction as a result of two possible mechanisms:

- changing geometry gives led to changing of the efforts status and the failure possibility by sliding of some fragments increasingly larger in the massif;
- local failure cause to raising material disposal in proximity areas, reducing its resistance to further evolution of the phenomenon of seizure and amplifying the causes that lead to this phenomenon.

Both mechanisms are characterized by an evolutionary process that may develop a very quick evolution. The main causes of local instability phenomena are erosions and hydrodynamic entrainment.

Erosions may be appearing due to waves and currents streams. Sometimes erosive action can be activated by the presence of bumps in the riverbed, forming pits and swirl areas which are particularly dangerous because they are not accompanied by external signs.

If the case of non cohesive soils subject to erosive action of surface water flow, critical speed drive by water particles depends on their size and their immersion specific density, is about 0.5 to 1.0 m/s for particles with a diameter of 0.01 mm, 0.15 to 0.30 m/s for the particle diameter from 0.1 to 1.0 mm and 1.0 to 2.0 m/s to 10 mm particles.

Hydrodynamic trailing occurs when the hydraulic gradient, i, is equal to a critical gradient, i_{cr}, which is defined by the relationship:

$$i_{cr} = \frac{\gamma'}{\gamma_w} \cdot \frac{\sin(\Phi' - \alpha)}{\cos(\Phi' - \beta)} \qquad (1)$$

where: γ' *is immersed volumic weight of soil*

γ_w *is specific water volume weight*

Φ' *is the effective internal friction angle of the soil*

α *is the leaning angle towards soil surface*

β *is the angle of current line on the infiltration water exit with the soil surface.*

Because any non-heterogeneous or anisotropy may lead to diversion of local current lines in the water outlet from the ground, one can consider of taking any value for angle β, in this situation the critical gradient will be the minimum value of i_{cr} as a variation of β in relation 2 and that for β = Φ ':

$$i_{cr} = \frac{\gamma'}{\gamma_w} \cdot \sin(\Phi' - \alpha) \qquad (2)$$

In practice one can observe that for the uneven non-cohesive soils, the i_{cr} value decreases considerably, probably because concentrations miscarriages in less permeable zones characteristic of such land. Laboratory tests and practical works have led all case horizontal surface of the earth and "bottom currents, the i_{cr} values of 0.5 to 1.0 when the degree of unevenness A ≤ 10 and 0.25 - 0.30 when A ≥ 20 (by V. Istomina).

3.2. Cyclic loads

There are a variety of cyclical loads, which differ by amplitude-time characteristic diagrams, leading to different responses of massive soil can or cannot be possible their nonlinear behavior in a linear elastic model, load applying duration had determinate influence on residual deformations, and hence over the qualitative and quantitative aspects of soil behavior.

Dynamic loads which can cause cyclical loads in soil can be classified as follows: natural (earthquakes, waves) and artificial (blasts, projectile impact, traffic, construction activities, machinery and equipments with unbalanced masses or who can cause shocks).

a. Harmonic loads (or simple periodic) can be represented by simple trigonometric functions sine or quasi-sine versus time. Harmonic soil load can be caused by waves, by the action of vibratory compactor cylinders, rotary machine, etc [1].

b. Periodic loads are characterized by an identical repeat after a minimum amount of time, T (period).

Periodic movements that cause this kind of loads can be decomposed by harmonic analysis (Fourier) in harmonic motion. Periodic loads can be generated by vibrating machines working with several different frequencies or other controlled actions.

c. Random loads (certain, non-deterministic or random) whose diagram feature is not ever repeated in time or identical. This type of loads are typical the earthquakes or dynamic loads generated by heavy vehicles motion.

d. Transitional loads are random and is characterized by the fact that, after a stop the momentum quickly reduce their vibration amplitude until the system returns to equilibrium situation required action prior pulse. Such requests are the result of shocks, namely the application of strength for a short time: falling stones, impact projectiles and explosions, beating pilots or even some types of movements seismic.

Frequency of the cyclical loads is an important parameter in terms of generating liquefaction phenomena in sands, in connection with this phenomenon is envisaged as a determinant factors the cycle’s number which, of course, for a certain period of loads is dependent of the frequency. It is however an indirect influence on the phenomenon of liquefaction when the massif put on load is partially drained; if for the same number of cycles the dissipation capabilities of pore water pressure are higher corresponding to a longer application, then liquefaction will be delayed [8].

4. CONCLUSIONS

As presented in the present paper, the phenomenon of liquefaction consists in temporary, totally or partially loss of the shear resistance of soils susceptible to liquefaction under the influence of external dynamic loads or monotonous ascending [7].

Knowledge of soil characteristics that influence their liquefaction potential is important at least to achieve two goals:

- predict the seismic behavior of the foundation soil on the basis of general data and possibly some additional investigations;
- obtaining of undisturbed and representative samples, and attempt to establish their scheme so that it is reproduced as faithfully conditions determined in nature, when carrying out a detailed analysis of sensitivity to liquefaction.

The complexity of the soil behavior, its non-homogenous, the limitations imposed by existing methods of investigation and the large number of parameters to be taken into account have made it difficult to elaborate up to present days, a generally valid pattern of behavior [3].

Modeling and a more precise quantification of motions on the construction, through the soil foundation by an earthquake creates a nearly complete picture of the difficulties that have to face in the soil mechanics civil engineer in soil massif soil behavior approach during an earthquake.

All this leads to the development of risk assessment methodologies to soil liquefaction capabilities in locations with potential risk areas.

A modeling and a more precise quantification of movements on the construction, through the soil foundation by an earthquake creates a nearly complete picture of the difficulties that have to face in addressing geotechnical engineer massive soil behavior during an earthquake.

Since each site has specific conditions, it is useful to consider the future construction site for assessing liquefaction potential, and to determine what factors may influence them. In this sense, these factors can be divided into two main categories: factors that influence the phenomena certainly presents a liquefaction and cyclic mobility and factors whose influence has been referred but clinical effects are not enough [5].

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