TIME EFFECTS ON LIQUEFACTION POTENTIAL

EFFETS DE L'AGE DANS LE POTENTIAL DE LA LIQUEFACTION DES SOLS

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SYNOPSIS

This paper presents first results of a research project which objectives are to determine pore pressure coefficients to relate dynamic water pressures generated in soil structures and seismic ground motions and to study the evolution of these coefficients as functions of time and the corresponding variations of liquefaction potential with age. The data are obtained by means of electric piezometers connected to an accelerograph station installed inside sand and silt deposits of a tailings dam. The importance of time effects in liquefaction phenomena is inferred from results of shear strength measurements, in-situ and in laboratory, plus experience of seismic behavior of tailings deposits of different ages.

INTRODUCTION

Time elapsed after deposition has important effects on shear strength of sedimented soils. This fact has been verified by in-situ measurements obtained with standard penetration, cone penetration and vane shear tests in old tailings deposits of sands and silts of different ages (Troncoso, 1990). Triaxial tests performed in undisturbed samples of silty sands have also shown significative gains in cyclic strength with age (Troncoso, Ishihara and Verdugo, 1988). Furthermore, inspections of seismic damages in tailings dams in Chile have lead to the conclusion that old abandoned deposits generally behave better than young deposits.

Since pore pressures are main variables in the processes of dynamic degradation of shear strength, liquefaction and flow failure, it is important to learn how do the pore pressure parameters evolve as functions of time. Therefore, the purpose of this paper is to present first results of a long term research project which is now under way with the objective to define dynamic parameters to relate stress paths and pore pressures in sands and silts and to determine the evolution of these parameters with age of the deposits.

EVOLUTION OF PORE PRESSURE COEFFICIENTS AND DYNAMIC BEHAVIOR

Pore pressure coefficients, A and B (Skempton, 1954), relate pore pressure changes with shear stresses and with hydrostatic stresses. B is a positive ratio which tends to one as the degree of saturation tends to one hundred per cent. A is positive for compressional soils and negative for dilatational soils.

A-values are directly related with the microstructure of the soils, therefore they depend on stress history, confining pressures and fabric. Microstructures change when fabrics or interparticle bonding forces change. Soil structures formed by deposition in seismic zones are subjected to periodic dynamic loadings which change the fabrics by rearrangement of particles, and induce transient excess pore pressures therefore altering the shear moduli and damping characteristics. Permanent changes in compressibility of the solid skeleton lead to different pore pressure versus stress ratios. In other words, dynamic pore pressure coefficients should evolve with seismic history.

On addition, other time effects such as: chemical reactions between component minerals of solid particles and double layer fluids, cementation due to oxidation, precipitation of chemical solutions or fusion at very large contact stresses, and leaching, may change microstructures of soils. Physical phenomena, such as consolidation, seepage and dessication also change the dynamic properties of the soils.

The dynamic behavior and the shear strength of soils change as result of the influence of the time effects in the mechanisms of pore pressure generation.

TIME EFFECTS IN SHEAR STRENGTH

In-situ measurements of shear strength performed in soil deposits of different ages have permitted to observe gains in strength with time. Results of penetration tests, such as shown in Figs. 1 and 2, performed in soils of well known histories, are useful to evaluate time effects in shear strength. These results could be later correlated with the liquefaction potential in accordance with experimental works presented among other authors by Seed et al (1984) and Yasuda et al. (1989).

SPT resistances may increase with age, as shown in Fig. 1, in deposits of silty sands. These results have been obtained in the deposits of soils identified as tailings dams El Cobre Nr. 4, El Cobre Nr. 3 and Barahona Nr. 1. All these deposits are sedimentary structures formed by hydraulic fill methods, so their histories start with transportation as suspensions in waters which contain chemical products added in mining processes. After sedimentation and consolidation the gains in strength have to be caused by seismic history and aging effects.

Cone penetration tests (CPT) have also revealed larger resistances in older than in younger deposits of similar silty sands, as shown in Fig. 2. Same tendency has been observed with vane tests (Troncoso, 1990).

The satisfactory behavior of many old tailings dams in strong earthquakes, even in cases when liquefaction of impounded slimes have occurred may be a consequence of positive time effects in the evolution of shear strength.

The testing procedures and the observations of the overall seismic performance of soil deposits are not sufficient to analyze the ultimate causes of time effects in liquefaction potential because they lack the direct measurements of pore pressures. Therefore, simultaneous records of pore pressures and seismic motions are necessary to study these effects.

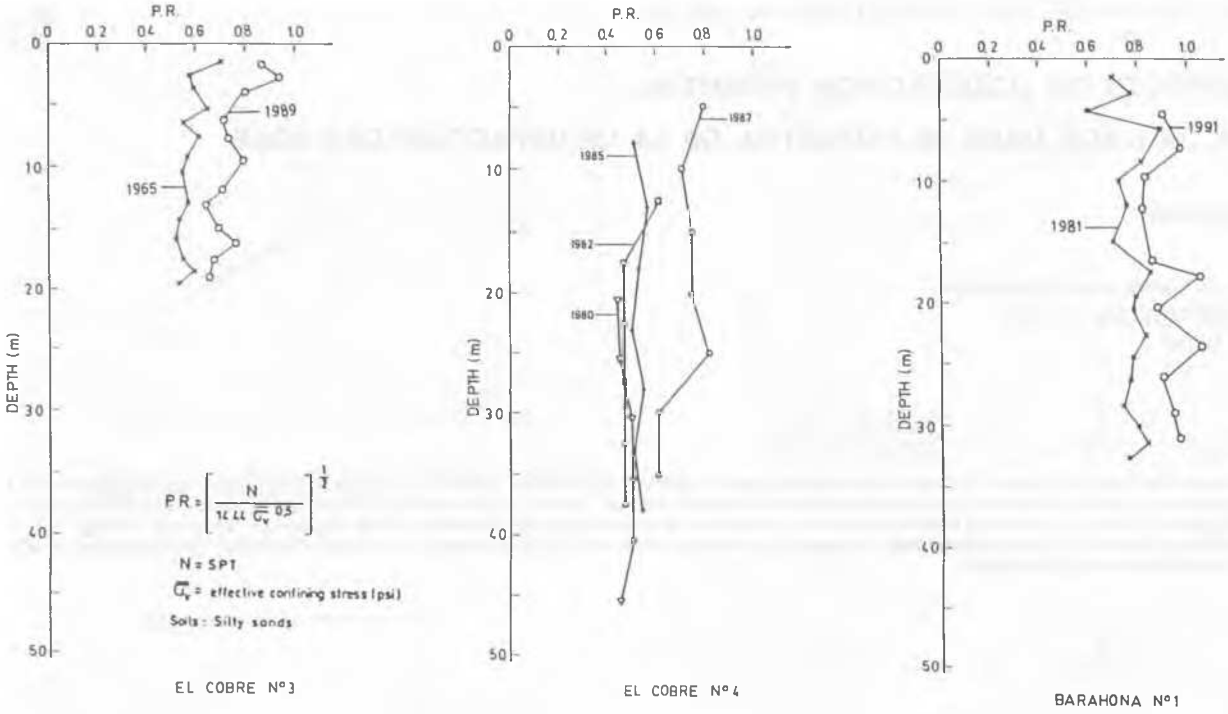

FIG. 1 TIME EFFECTS IN STANDARD PENETRATION RESISTANCE (SPT) IN SILTY SAND DEPOSITS

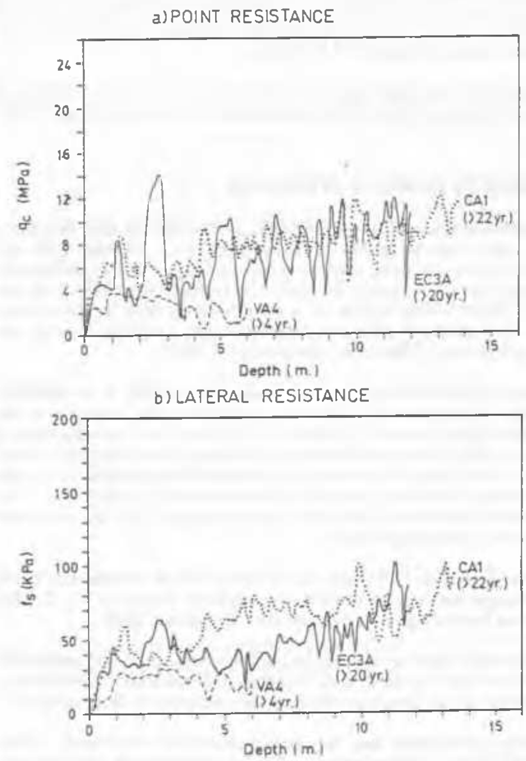

FIG. 2 TIME EFFECTS IN CONE PENETRATION RESISTANCE IN SILTY SAND DEPOSIT

TIME EFFECTS IN SEISMIC PORE PRESSSURES

The most direct way to monitor time effects in liquefaction potential is to measure excess pore water pressures generated by different events, such as earthquakes, as they occur along the life of a soil deposit. This idea has guided the installation of dynamic piezometers in a tailings dam similar to an scheme originally developed by Ishihara et al. (1981). The installation has been described by Troncoso et al. (1990) and it consists in one accelerograph station and three dynamic piezo-electric sensors connected to same recorder in such a way that simultaneous measurements of vertical and horizontal accelerations plus pore water pressures are obtained every time a seismic event occurs.

Since this seismic instrumentation system was installed, in July 1990, only minor tremors have hit the site, and therefore, collected information has been limited. A summary of recorded data is shown in Fig. 3; it is observed that larger excess pore pressures correspond to silty sands with higher initial piezometric head as measured by Piezometer No. 3. The results are being analyzed to disclose possible time effects. Although it is recognized that the collected data so far is not enough to obtain conclusions, there is a tendency shown to lower pore-pressure increases in more recent events.

The system shall be upgraded in 1993 with two additional piezometers in order to increase the information to be collected in future major earthquakes.

The expected results of this research are curves of pore pressure increase versus accelerations and stress ratios, for different time periods, with the purpose to verify how aging and seismic history change the pore pressure coefficients.

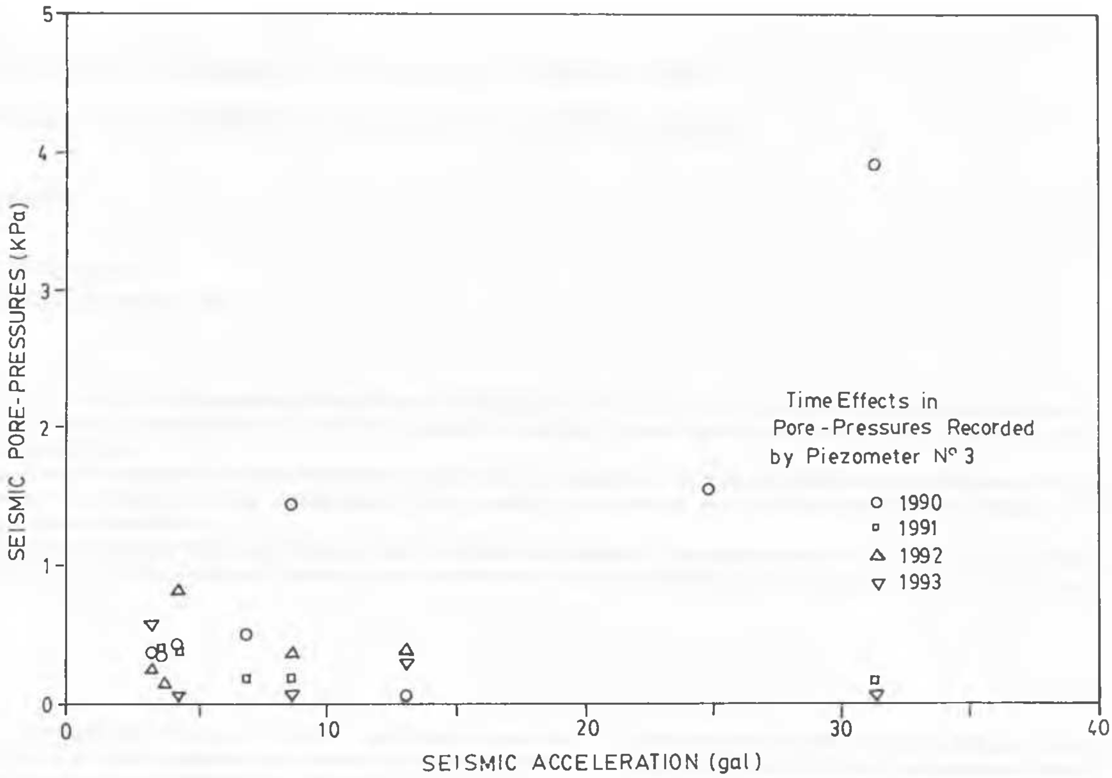

FIG. 3 SEISMIC PORE PRESSURES VERSUS ACCELARATIONS AND TIME. VETA DEL AGUA SILTY SANDS

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