28 Apr 1981, 9:00 am - 12:30 pm

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Proceedings: First International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, April 26 - May 3, 1981, St. Louis, Missouri

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INTRODUCTION

A brief evaluation is made of research conducted to determine liquefaction potential for the sandy soils along the coastal areas of Peru, which present such characteristics that make them susceptible for development of this particular phenomenon under a very intense earthquake. It has been determined for the specific case of the Chimbote area, that some parts of the city present dangerous unstable conditions due to the present position of the water-table level, soil type and their relative density, that caused liquefaction during the 1970 earthquake.

On the other hand, in these areas the simplified method has been employed to establish the soil liquefaction potential with the help of plentiful field tests and information, comparing these evaluated results with other most sophisticated methods based on the propagation of shear waves employing the continuous solution of the wave equation, taking into account the longitudinal and transversal components of the 1970 Peru earthquake and three different base acclerations. Also, the prediction conducted, which recommends the lowering of the water-table to convenient depths, shows that the danger of liquefaction diminished in the investigated area.

DATA EVALUATION

We have tried to collect the most data available about field and laboratory of some regions in Peru, where the liquefaction phenomenon has occurred (Carrillo-Gil, 1970; Carrillo-Gil, 1977) and some other areas that such relatively uniform cohesionless soils presents a grain size distribution in such a way that this phenomenon can be considered susceptible to occur during a severe earthquake.

The results of this research gives us an evaluation of several tests conducted in Chimbote and Samanco areas (Japenese Mission, 1971; Carrillo-Gil, 1976), which established soil behaviour before and after the 1970 earthquake in Ancash region, located at the northern side of Lima, Peru; which shows that there are deposits of saturated sandy soils due to the presence of water-table very close to the surface in some zones (variation 0.00 mts. to 4.00 mts.) and taking in account the typical ranges of variation in the standard penetration test and grain size distribution (Fig. 1) it is possible a

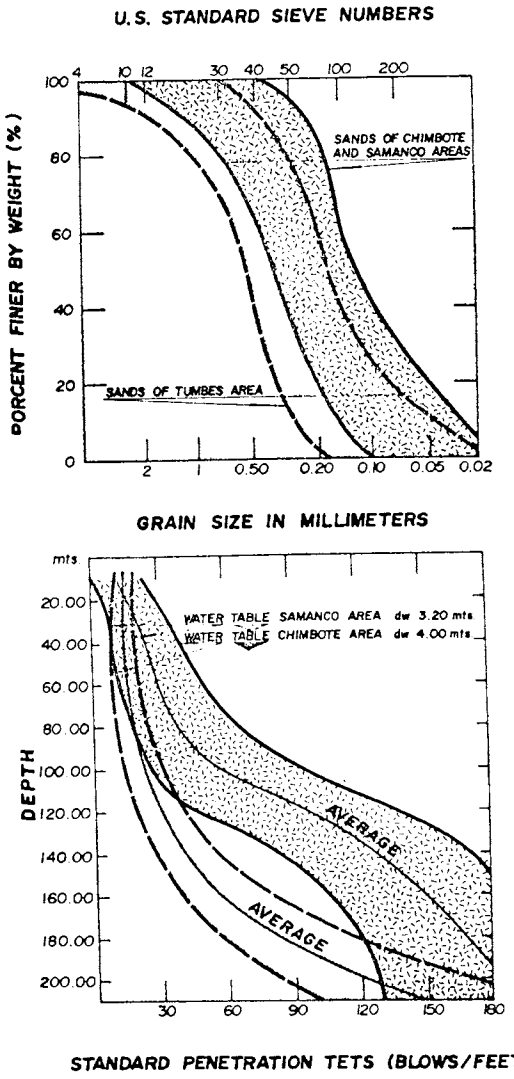

Figure 1. Envelopes of S.P.T. and Gradation Curves for Soils Tested.

statistical comparison with the same cases that has occurred in some other areas in the world (Kishida, 1969; Ross et al., 1969). For the heavy damage area of Chimbote it has been determined that the 62% of the samples shows the uniformity coefficient ranged between 2.00 and 8.97 and the 10% size (D_{10}) in 87% of samples is between 0.010 mm to 0.15 mms.

For the downtown of the city in which the averager water table depth is 1.50 mt. we have the 70% samples exhibit uniformity coefficient lies in the range 2.08 and 10; and effective measurement (D_{10}) between 0.011 mms to 0.18 mms and 53% of the standard penetration resistance done in the area, give values less than 15 blows/feet. For the area located in the humid zone of the southeast of the city with the water-table to a variable depth between 0.00 mt. and 1.00 mt., the grain size verification shows that 63% of samples tested has uniformity coefficient values ranging between 2.0 to 10.5 and effective diameter (D_{10}) of 83% from the whole ranged between 0.037 mms and 0.21 mms, and besides we found that the 18% of standard penetration numbers shows values less than 15 blows/feet.

The expansion zone that takes more than 14 km from the downtown toward south with water-table to a depth more than 8.00 mts., makes less susceptible to undergo the phenomenon, although 71% of tested samples has a uniformity coefficient ranging between 2.5 to 8.0 and 85% of samples shows the particle diameter between 0.05 mms and 0.25 mms. In this area nevertheless the relative density is low, ranging lightly between 11 blows/feet to 17 blows/feet.

COMPARISON OF RESULTS

The simplified procedure for evaluating soil liquefaction potential used for the research areas (Seed and Idriss, 1971) determine the cyclic shear stresses that cause liquefaction of a specific soil in the same number of stress cycles based on known conditions that has caused liquefaction of sand in previous earthquakes (Carillo-Gil, 1978).

The analysis of information of several cases where the phenomenon has occurred and the utilization of approximate relationships that let us determined the shear stresses developed at any point in a soil deposit during an earthquake is great enough to cause liquefaction, has been applied to the more critical zones in Chimbote and Samanco areas where has been detected liquefaction (Carrillo-Gil, 1975), having found for many practical cases the employment of this simplified technique combining with field data can be enough for the requested evaluation since that relation between maximum ground surface acceleration and its relative density can be calculated for specific conditions in each soil type, shear stress and water-table depth (Fig.2) taking stress ratio between 10 cycles and 30 cycles and taking into consideration that we have a variation of mean grain size (D_{50}) and we expect the earthquake will produce such a cycle shear range (N_c) the limit condition will be covered when we will consider in the calculation the minor (D_{50}) with the major N_c and the major D_{50} with the minor N_c.

On the other hand, we have done verifications with other methods more elaborate, among them the Shake 3 (Alva-Hurtado, 1978), based upon continuous solution of vertical propagation equation of shear waves, having taken average values of standard penetration test and the correlating variation of water-table depth, adopting different base accelerations and the

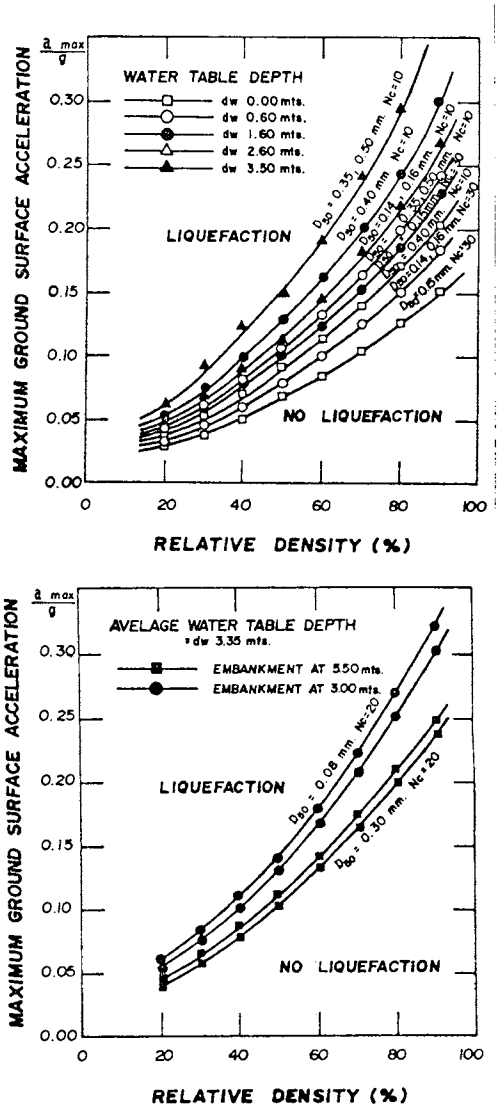

Figure 2. Evaluation of Liquefaction Potential for Chimbote Area.

longitudinal components of 1970 Peru earthquake.

From the comparison of liquefaction potential evaluation with Shake 3 (Schnabel et al., 1972), and simplified procedure (Fig. 3) it becomes established that both methods give similar response curves in practical terms. In the same way we could prove the results of a preliminary investigation carried out in 1975 with analytical solutions more elaborated with respect to the convenience of dewatering and drainage and diminish the liquefaction potential in that area, getting a reasonable analytical verification (Fig. 4) since for positions of ground water levels less than 4.00 mt. the influence of pore water in the soil will not be significant and therefore the phenomenon will not occur.

CONCLUSIONS

The application of simplified method in the research area it is a helpful guide to determine the probably behaviour of saturated sandy

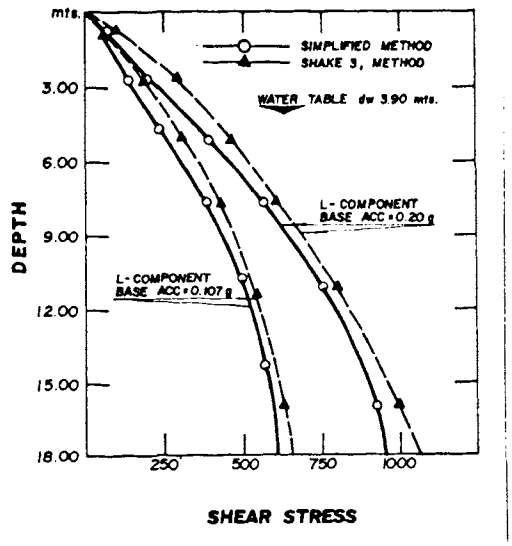

Figure 3. Comparison of Shear Stress for Shake 3 and Simplified Method.

deposits for many practical purposes when a severe earthquake occurs.

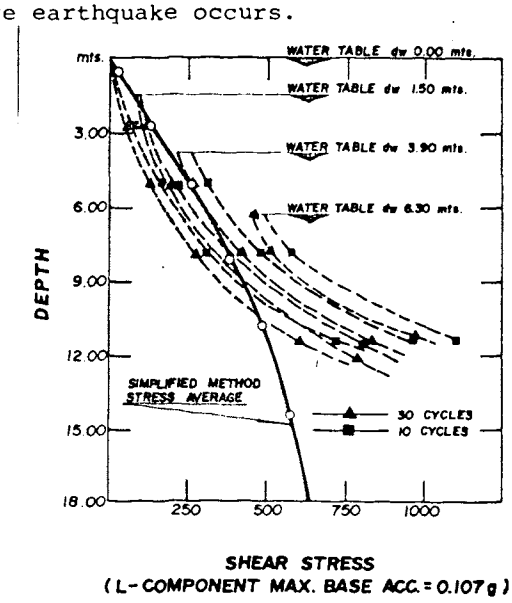

Figure 4. Computed Variation Between Water Table Position and Simplified Method.

It has been established that the investigated area probably will produce at some depth below the ground liquefaction in the surface layer since 5.00 mts., to 6.00 mts. in depth in the critical zones of Chimbote, considering improbable the appearance of phenomenon in deep strata due to the relative density of soil and position of water level all of which has been proved analytically and by experience in the last earthquakes underwent in the area.

From the carried out evaluations it is determined if there will be a new severe earthquake such as the one of 1970, the region undergoing again the investigated phenomena with the consequent materials and humans lost, nevertheless, as a result of this research we had taken the necessary precautions to carry on an integral program of underground drainage of the area so can get lowering of ground water level and to diminish the danger since it has been demonstrated that the liquefaction potential will diminish when the water table is located deeper.

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